Al-Rafidain Engineering Journal (AREJ) Vol.28, No.1, March 2023, pp. 300-311

# A Review of Issues and Challenges to Address the Problem of Implementing Green Computing for Sustainability

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Received: 2022-8-24 Accepted: 2022-10-8

***ABSTRACT***

*In a larger sense, "green computing" refers to strategies and procedures for creating, utilizing, and disposing of computer resources in three ways: maintaining total computing performance, minimizing the impact on the environment, and maintaining overall computing performance. This entails using less dangerous materials, getting the most usage possible out of a product while using the least amount of energy possible, as well as making old items and the garbage more reusable, recyclable, and biodegradable. Many businesses are making efforts to lessen the negative effects of activities on the environment. The framework Convention on Climate Change of the United Nations (UNFCC)is a global environmental agreement whose goal is to keep greenhouse gas emissions stable to a degree that would prevent adverse anthropogenic interference with the environment. Sustainable development entails growth that doesn't jeopardize the needs of coming generations. That is achieving human development goals while protecting the ecosystems and natural resources that are essential to civilization. The relevance of green computing for sustainable development is emphasized in this paper's assessment of many significant recent studies on the subject.*

***Keywords:***

*Green computing, Green IT, Sustainability, Energy efficiency, Greening data centers, power consumption*


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## 1. INTRODUCTION

Green computing refers to the study and use of effective, efficient, and cost-effective computer resource use. Virtualization, Power Management, Material Recycling, and Telecommuting are some of the several green computing strategies [1][2]. Sustainable business practices are now being included in the creation and maintenance of information technology systems and components by IT corporations [9].

The original goal was on making computer assets more efficiently used to reduce energy consumption and the associated carbon emission effects. The first generation of sustainable IT, known as "green IT," can be perfectly described by the reduction in data processing energy usage in data centers and throughout the company. The second generation which is already forming will be considerably more difficult for IT managers to define and successfully overcome [3][5][10]. IT products and services nowadays are commonly available in industrialized countries and are fast getting momentum in emerging economies. Concerning its benefits and drawbacks for the community, information technology has gained a great deal of publicity. Government regulation and shifting market demands will be the main forces behind the development of sustainable IT [1][4][12]. To establish sustainable IT leadership, proactive IT managers must get ahead by creating an efficient market, product/service, technology, and organizational roadmaps.This will probably need IT departments to go beyond just functional needs and adopt a more strategic position as a major facilitator of business sustainability and social responsibility initiatives [3][20][21]. As IT managers have grown more conscious of how IT affects society and the environment, the idea of "sustainable IT" has grown in favor. Beginning with the Energy Star program in 1992, this recognition has quietly grown over the past 20 years. The first development of sustainable IT solutions, often known as "green IT" or "green computing," was spurred by the Internet-driven fast rise of datacenters, their related energy costs,

and their carbon footprints. [8][9]. For large-scale e-commerce enterprises, datacenters can consume up to 50% of energy expenditures and 25% or more of overall IT budgets [7][14][29][31]. Green computing also aims to minimize the use and disposal of hazardous chemicals, save water and other finite resources, and cut down on IT-related waste to regulate and lessen the environmental impact of IT operations. The increased focus on green IT has produced well-defined energy-saving solutions that are simple to deploy, give the advantages of reduced costs, and smaller carbon footprints, and frequently improve the performance of datacenters and IT operations.

Future energy consumption and environmental restrictions, along with those advantages, will make green IT development a top focus for IT firms for a very long time.[8][9][18]. The goal of green IT is to make IT operations more energy-efficient. Customers and other stakeholders only receive a secondary advantage from the corporation's cost-cutting and energy-use compliance initiatives. Cost savings may not be transferred to consumers in the form of cheaper prices. The business community may come under increased pressure from the media and other stakeholders to enhance a wider variety of environmental, moral, and social implications of their IT-related commercial activities from governments, non-governmental organizations (NGOs), unions, and other stakeholders [29]. Companies must assume much greater responsibility for enhancing product and service design, rethinking the value chain, and greening IT processes to not only solve the environmental and social issues that arise from the use of their products but also to use those products to address a wider variety of social and environmental challenges [7][8][35]. Therefore, "sustainable IT services (SITS)" is the newly emerging second round of tactics that are advancing sustainable IT beyond the green IT concentration on energy saving to one of developing a framework for sustained IT innovation that is service-oriented.

This platform will create programs to deal with a variety of environmental and social problems that affect businesses, the entire value chain, and society at large. SITS emphasizes innovation and putting the business in a leadership position for IT-enabled corporate social responsibility (CSR), whereas green IT is about internal cost reductions. [44]. If competitive advantage is to be achieved at the corporate and social levels, this larger approach to sustainability will necessitate changes like how value is conceptualized and provided [12][40]. SITS strategies will encourage innovation, create new markets, redefine procedures, and call for adjustments in IT firms' culture and operations.

The new sustainable IT charter will include the business function of the IT organization with standards for social responsibility and global sustainability. [8][39].

These modifications reflect a change in client demands from a major focus on concrete cost-benefits of IT as a product (such as decreased energy use) to the more ethereal green advantages of sustainable IT as a service for establishing socially responsible business models. [8][46]. It is interesting to think about how the sustainable IT discipline could grow in the future given the complexity and evolution of the field.

## 2. GREEN COMPUTING

The goal of green computing, often known as green IT, is to lessen the carbon footprint created by the information systems industry while also enabling cost savings. The term "green IT" refers to information and communication technologies whose development or application might lessen the adverse consequences of human activities on the environment. Sustainability in the environment is referred to as "green computing" or "green IT." [17][19].The two categories of software technology and hardware technology may be explored with green computing. Software technology has several facets, including design techniques that increase program efficiency, use less storage space, and consume less power. It also covers computer paradigms like Cloud computing, distributed computing, and high performance computing which are just a few examples. There are numerous technologies on the hardware side which are being implemented to improve economic efficiency, recycling technology, and minimize energy consumption and environmental footprint. At the same time, technical assistance is accessible through human factors engineering [25].

## 3. THE BENEFITS OF GREEN COMPUTING

Green computing is the process of making better use of computing resources while preserving or improving overall performance. The practice of "green computing" involves maximizing the efficient use of computer resources to lessen their adverse impact on the environment [33] [40][42]. This encompasses the objectives of limiting the use of hazardous chemicals, energy, water and other limited resources, as well as decreasing waste generated during production and throughout the supply chain. The usage of a product throughout its

lifespan, as well as the recycling, reuse, and biodegradability of outdated items, are all aspects of green computing.[1][3].Therefore, "green computing" refers to the development and application of information systems that support environmentally friendly corporate practices. Green IT addresses issues like:

• Switching from desktop computers to thin clients.
• Using virtualization software to run multiple operating systems on one server.
• Using renewable sources of electricity to power data centers.
• minimizing disposal of outdated computing equipment.
• Creating energy-efficient semiconductors and disk drives.
• Promoting telecommuting and remote desktop management to avoid waste [5].

The global advantage is that it aids in lowering energy requirements, waste, costs, and how we utilize technology, all of which have a good impact on the environment. Some of the advantages of green computing are shown in Table I in Reference [11] [14].

Table 1Some benefits of green computing.

| tangible advantages | Intangible benefits | Benefits for a company |
|---|---|---|
| Capital improvements | advantages for theenvironment like pollution controls | decrease total energy use |
| savings on maintenance | economic advantages (Ecologically sound development) | Reduce data-center footprint |
| Better and safer lighting | Social benefits | Encourages efficient utilization of natural resources |
| E-waste reduction | Controlled secured head disbursement problems | Increase server performance and capacity. |
| Energy saving and efficiency | Increased user efficiency | Virtualization reclaiming precious floor space |
| Space saving | Simple and reliable IT infrastructure | Provide rapid and secure access to required data |
| Technological advancement | It is simple to test application software across several platforms. | Streamline the administration of systems and solutions |
| traveling less | Emotional risk | Recycle |
| (Video conferencing & collaboration) | minimizing | outdated technology |
| Utilize resources more efficiently | Behavioral risk minimizing | Free-up budget components |

## 4. ENERGY EFFICIENT FOR GREEN COMPUTING

Any action that uses less energy is considered to be an act of energy conservation. Utilizing technology that uses less energy while yet performing the same job is known as energy efficiency. Energy efficiency is exemplified by a compact fluorescent light bulb, which uses less energy to provide the same amount of light as an incandescent bulb. The focus of energy sustainability is on long-term energy planning and laws that ensure there will be enough energy available to fulfill both today's and tomorrow's demands. Sustainability also entails funding advanced technology research and development for conventional energy production, advocating the use of alternative energy sources, and supporting responsible environmental legislation. [15]. A few years ago, energy effect as contemporary computer systems, including data centers, continue to use vast quantities of electrical power, energy efficiency has become one of the most crucial design criteria. This hurts the environment in terms of huge emissions of carbon dioxide in addition to high running expenses for computer resources. For instance, the current CO2 footprint of IT infrastructures is roughly 2%. Without the development of energy-efficient methods and computer resource management algorithms, IT impacts on global energy use and CO2 emissions are predicted to increase quickly. When seen from the data center's perspective, the power management problem becomes much more problematic. To reduce energy usage, the system in this instance is represented by a collection of networked computer nodes that must be controlled as a single resource. In the era of climate change and global warming, this is manifestly unacceptable [10][15][16]. According to reference [2], there are several indicators for energy efficiency, such as total power usage, which was the most widely used statistic, according to 68% of IT managers.

The baseline evaluation normally takes into account the cost of energy and the number of kilowatts consumed. This measure may be used to monitor how much energy is used by a facility, a function, an application, and a worker. Since

power costs can be easily traced and make up a significant portion of the IT budget, accountability for electricity usage by IT businesses has been highlighted. Making the cost of power, a separate line item in the IT budget encourages improvement in efficiency and results in cost savings. Effectiveness of power use was another measure (PUE). Total Facility Power/IT Equipment Power is the same as PUE. Power for IT equipment is referred to as the burden placed on computers, storage, network hardware, and peripherals.The total power measured at the utility meter is referred to as total facility power.

A PUE of 2.0 means that the electricity required to power the IT equipment is twice as high as the demand for data centers. With all of the power used by IT equipment, a PUE rating of 1.0 would represent 100% efficiency. Infrastructure efficiency in data centers (DCiE). DCiE = 1/PUE The PUE is the same as this ratio. In the aforementioned illustration, the data center's IT equipment consumes 50% of the electricity. Typically, cooling uses the other 50% of the energy consumption. Since less energy is used for cooling as IT equipment becomes more efficient, DCiE will rise as a result. Data center performance efficiency is the third metric (DCPE). Useful Work/Total Facility = DCPE Power [22],presents an energy-saving system based on metrics to divide data centers into quantifiable pieces, and then uses green metrics to make efficiency measurements and benchmarks possible[15].

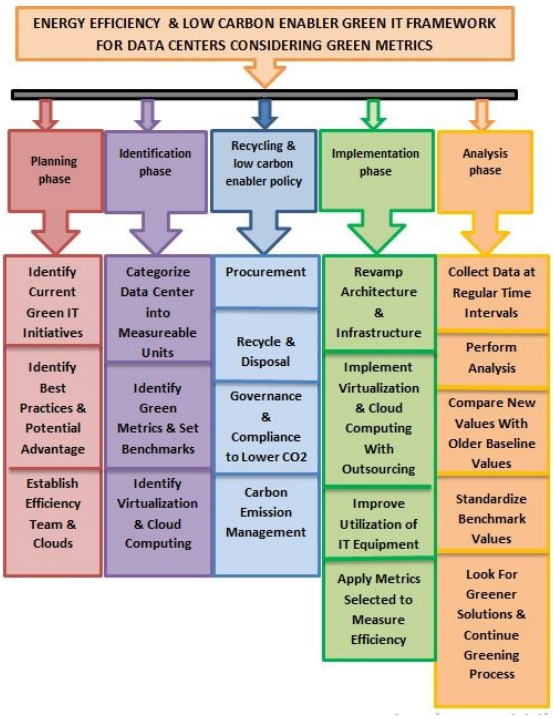


Fig.1. Energy efficiency and low carbon enabler green IT framework for data centers[15]

## 5. BACKGROUND AND RELATED WORKS

Stephan Niggeschmidt[6] Life cycle costing (LCC) has been used by a growing number of machine tool sector clients to analyze the cost-effectiveness of various investment alternatives. Since maintenance expenses have shown to be one of the most significant cost drivers, they have mostly been employed to address them. The life cycle performance (LCP) method expands on LCC by taking into account the link between a machine's expenses and benefits throughout its full life cycle. Given the growing significance of environmental awareness, the environmental effect must now be taken into account while appraising machinery. The incorporation of green manufacturing ideas into LCPevaluation is made possible by a framework that is offered. The approach provided in this study makes it possible to include green manufacturing ideas in LCPevaluation. It has been demonstrated how to gather the data needed to assess a system's performance in terms of dependability, serviceability, and energy usage.

Moreover, the most appropriate measurements and methodologies have been discussed. By examining how much energy is used by a machine, the suggested framework complements the LCP method and will assist to increase the accuracy of any forecast.

Sara S. Mahmoud [13] Since there is currently no accepted paradigm for defining data center's "greenness," various metrics have been developed in this study to quantify all the energy-wasting variables. We gathered the majority of the GPIs created by various associations and organized them into four main categories that were recognized by the EU Project GAMES. In these categories, each measure is defined, compared to others in the same category, and frameworks are organized for each category. Incorporate a technique on the metrics gathered with improvements and compare and contrast three alternative procedures that outline approaches for unification.By using lessons learned based on the accumulation of historical monitoring data for the related GPIs, it will be possible to better understand the complex correlations and dependencies between GPIs in the same class in the future.

Mueen Uddin [15] To improve power and energy efficiency in data centers, this study suggests a Green IT Framework that makes use of virtualization technologies and green metrics. It is

a framework for implementation that data center administrators may use to appropriately integrate green IT technology into their facilities. It consists of five phases, each of which outlines the procedures required for correctly implementing green IT technology in data centers. By applying the suggested energy efficiency low carbon enabler framework utilizing green metrics, the framework offers data center administrators an immediate answer to enhance the performance of their current data centers. To lessen the consequences of global warming, it also helps minimize greenhouse gas emissions.

Rahul Baidya [18] The recycling of waste electrical and electronic equipment (WEEE) in India is examined in this essay as a green computing strategy. WEEE recycling has been shown to have a lot of room for improvement, and the issue of green computing may also be addressed at the same time. There is a lack of integration between the green computing approach's characteristics and issues of e-waste management. By adopting ARF through the proper process, WEEE recycling may be targeted toward best practices. The objective of green computing techniques will be improved with the reuse of resources and more understanding of the benefits of utilizing outdated computers, IT peripherals, etc. As a result, it is possible to optimize resource usage while reducing co2 emissions.

Sr. Jainy Jacob M [19]. The comprehensive problems for environmental sustainability are covered in this essay. Environmental overall specifications must be integrated into every aspect of the IT infrastructure even as new industry technology continues to increase efficiency.

Jinsong Wu [21] To introduce fresh perspectives and potentials for green metrics for the future of big data, this paper first conducts a thorough literature review on how to green big data systems in terms of the entire life cycle of big data processing. It then examines the relationship between big data and green metrics and suggests two new metrics: effective energy efficiency, and effective resource efficiency.

Deepanjan Sen [40] In this essay, the focus has been placed on adopting green computing to reduce the energy and carbon footprint of computers and the linked resources they use such as displays and printers. The major emphasis and main goal of this essay are the power consumption and carbon emissions of computers and their accessories. In this area, research is being done to cut back on carbon emissions and energy use. Only a few studies have looked at power-aware hybrid deployment, power management utilizing green algorithms, information resource tier optimization, architectural complexity reduction, and green software. Data centers and network equipment use a lot of power and produce a lot of carbon emissions. The carbon emissions from data centers rank second in the ICTs after computers and their accessories, carbon footprint. Optimizing data center power management and carbon footprint is one of the most important study areas now.

Emmanuel Okewu [23].Communication andIT for development (ICT4D) has emerged as a new discipline. This research has a special focus on green computing in Africa, whichwas still motivated by the need to assure ecologically friendly computing. In the light of this, it is believed that the continent would suffer the most from the impact of environmental risk and the susceptibility to climate change. This research measures the amount of Africans' awareness of green computing using Nigeria as a test case and a sample survey.To maximize citizen awareness in the face of inherent uncertainties like limited bandwidth, a shoddy network, and unstable electricity in a growing African market..... It also makes an effort to institutionalize the green computing maturity model. To identify the most effective sensitization technique, they categorized the issue as a stochastic optimization problem and used a meta-heuristic search method. Although there are other ways to encourage green computing education, the meta-heuristic search the researchers conducted revealed that the most cutting-edge approach is an online real-time solution that not only encourages but also maintains timely conversations among the public about electronic waste management and energy-saving techniques. To model the suggested solution using Universal Modelling Language (UML), the researchers studied the literature, gathered needs, and developed a model. A web-based, multi-tiered e-Green computing system is the suggested remedy; it instructs computer users in cutting-edge methods for handling computers and peripherals in an ecologically beneficial manner. They discovered that a real-time web-based interactive forum like this increases people's awareness of the effects of their use of computer on the environment in addition to piquing their interest in environmental concerns.

By doing this, he voluntarily contributes to the effort to reverse environmental damage in his area of responsibility.

Bokolo Anthony Jnr [24] This paper focuses on the use of green computing in “data

centers", which contain servers. As a result, it proposes best practices for green computing life cycle management that may be used in data centers in IT-based enterprises. 133 users in companies with in-house data centers filled out a questionnaire to provide the statistics.The life cycle methodologies for green computing outlined in this research were validated by data analysis. According to the statistics, each life cycle strategy plays a vital role in helping IT-based enterprises implement green computing techniques in their data centers.

Kumar Gourav Arora[25]. This essay demonstrates the value, difficulties, and need for green computing. The IT industry is working to achieve Green computing in all areas.The main projects for green computing include equipment recycling, cutting back on paper use, virtualization, cloud computing, power management, and green manufacturing. Researchers and organizations are working hard to develop eco-friendly technology. The firms' current green computing strategies include power management methods, virtualization, enhanced repair, re-use, recycling, and disposal, data center consolidation and optimization, IT product and eco-labeling, and data center consolidation.

Ahed Abugabah[26]. This research focused on how green ideas, green programs, green buildings, and green regulations may decrease energy use and carbon emissions, minimize waste, save costs, and preserve the environment. Even while the students are familiar with green computing in principle, they lack implementation skills. The practical use of green computing seems to be underrepresented. For the study's findings to contribute to the body of research, it attempted to evaluate how university students behave and use green computing.

Nsikan Nkordeh[28].This study is devoted to discussing current developments in the theoretical 5G mobile technology, which is the energy-efficient technology for sustainable network rollout. This article investigated the cutting-edge technology anticipated to enable sustainable, unproven 5G networks and presented a viewpoint on environmental considerations in response to the design of the 5G cellular environment. The green expectation for 5G networks is met by power harvesting techniques, which also impart green practices for improved spectrum utilization. 5G networks with reduced power requirements may be used in 5G technologies. examining the confidential communications on potential future user traffic, channel, energy use, or even content

AdedapoOluwaseyiOjo [29] In this study, a sample of IT professionals working for ISO 14001-certified IT organizations in Malaysia were assessed for their attitudes about GIT, as well as the mediating impacts of their attitudes toward GIT. This study also looked into the connection between GIT attitudes and behavioral shifts, as shown by self-reported participation in green computing activities. 333 people were surveyed to gather information. The findings confirm that GIT attitude is directly influenced by GIT knowledge, social impact, and green management culture. However, for GIT knowledge and social impact, but not for green management culture, the expected indirect effects through the mediation of GIT beliefs were supported. Support was shown for the association between GIT attitude and participation in green computing techniques.

Archana Patil [38] This study gave a literature survey on green cloud computing and research analysis of the topic. A quick overview of the cloud computing idea and the necessity of developing green clouds. In the literature study, researchers from the past who studied green clouds were highlighted. Their work revealed problems and suggested fixes. We provided a detailed presentation of the green cloud computing architecture and related components.

This paper's primary goal was to examine the salient features of green cloud computing while taking into account past research discussions, current trends, and next research challenges. The writers of this publication created it as a condensed guide for green cloud research academics to comprehend the characteristics of green cloud computing.

YiqinDeng, [39] This study examines newly developed delay-constrained IoT applications. The GS-MEC architecture is suggested to use the gathered energy in the IoT environment and lower the maintenance cost of replacing batteries for IoT devices. To increase the timeliness and dependability of task processing, they construct the challenge of reducing reaction time and packet losses within the constraints of energy queue stability. The DPCOEM algorithm is created to address the posed issue. The algorithm allows for the determination of the following time slot's ideal variables: IoT devices' energy harvesting,the transmit energy, CPU frequency, and offloading decision vectors scheduled for Internet of Things devices. The suggested DPCOEM method beats the other three algorithms in every way when the varied variables of task arrival probability, average energy harvest power, deadline, and

distance are taken into account, according to theoretical analysis and simulation.

SrimoyeeBhattacherjee [46] This study thoroughly examines the many methods used to reduce energy usage in data centers. Additionally, it investigates and suggests ways to lessen the same, finally resulting in a greener environment. The Minimization of Migration (MM) strategy for a large historical data set has been adopted and implemented in this study, and a dynamic thresholding technique has been used in place of static thresholds. A decrease in the energy usage of cloud data centers has been observed after careful calculations.The creation of a green cloud network using resource-management strategies is thoroughly examined in this article. It exposes us to numerous strategies that may be used to deal with the worrying problem of excessive energy use in clouds. It examines the power and energy models now in use, as well as the VM placement and effective migration rules. A prediction-based migration strategy, or PMM, has also been suggested. Compared to MM, it requires fewer virtual machines (VMs) to be moved and uses less energy in data centers.A key finding in this regard is that a huge collection of workloads creates a lot of historical data, which results in more accurate predictions. This aids in making wise decisions and finally results in less energy use. APMM has distinguished itself as a unique addition to this endeavor.

Md. Sanwar Hossain [30] In this article, A hybrid architecture for energy-trading between grid supply and base stations (BSs) is presented to alleviate the utility grid's current power issue, increase energy independence, and reduce costs. The ideal size, technical requirements, energy output, and various prices have been assessed in the light of the sun's dynamic behavior, the volume of traffic, and the typical biomass's energy potential. Additionally, spectral efficiency and total possible throughput for wireless networks (SE), Employing MATLAB-based Monte-Carlo simulations, multipath fading, system bandwidth, transmission power, and inter-cell interference (ICI) are all taken into account as we thoroughly study energy efficiency (EE). The numerical outcomes show that the energy-trading facility may reduce greenhouse gas emissions by up to 65.8% and 3.20 percent of the net present cost (NPC), respectively. Final results include a full benchmarking comparison of the hybrid solar PV/BG system's performance against standalone solar PV, hybrid PV/wind turbine (WT), and hybrid PV/diesel generator (DG) systems in both on-grid and off-grid configurations.To lower both the net present cost and the carbon content of the LTE macro-base stations, this article investigates the viability of implementing a combined solar PV and biomass-focused sustainable supply system. By adjusting system parameters like transmission power and system bandwidth, the recommended system's sensitivity has been assessed by using the HOMER program in terms of optimal architecture, energy output, capital cost, and pollution rate.

Isabel Ruiz-Mallén [31] The sustainability mandate of the Agenda 2030 has been examined in this study's examination of how networks of higher education institutions (HEIs) at both the global and regional levels conceptualize and structure their suggested practices. The research presented in this study demonstrates that, for the most part, HEI networks' paths toward sustainability are framed within a "greening" paradigm, which seeks to improve both nature and human health by depending on less harmful types of economic growth as being by the objectives of Agenda 2030. By doing this, these networks encourage the incorporation of sustainable ideals into the organizational, academic, and strategic planning of HEIs, highlight the importance of collaborations, and support initiatives that primarily focused on teaching and learning. The four worldwide networks examined (GUNi, IAU, HESI, GUPES) and four of the six evaluated HEIs networks at the regional level all support this "greening" rhetoric (COPERNICUS, ASHEE, SDSN, PROSPER.Net).The results also highlight two marginal viable routes that only a few HEI networks are taking. One way that the African network (AAU) understands sustainability is through "resilient" rhetoric that emphasizes enhanced control over nature and the use of technical solutions to achieve the Agenda 2030 goals. This network seeks to transform HEIs into proactive agents of change and reliable providers of solutions to social problems, with community action being one of its primary supported activities.On the other side, the Latin America network (ARIUSA) bases its view of sustainability on an "alternative" rhetoric that advocates prioritizing human welfare over economic growth and, in doing so, calls into question Agenda 2030's strategy for sustainable development. The primary goal of this network, in contrast to the other examples, is to promote organizational change inside HEIs by institutionalizing sustainability issues within academic institutions, with academic cooperation being a crucial action to be enforced.

TeijoPalander [32] In this essay, the author discusses how the forest sector may reduce

its environmental sustainability obligations by expanding logistical operations. Indicators of energy efficiency for carbon-neutral transportation were created in this study. The most reliable model for the development indicator was the wood-based energy efficiency metric (payload's renewable wood energy/fossil transport energy). The indicator revealed that, in 2014 and 2016, synchronized transportation system fleets (60, 64, 68, and 76 t) and (64, 68, and 76 t) were, in fact, carbon negative (122, 133, 144, and 108) (142, 147, and 133) (value of 1 means carbon-neutral transportation).These beneficial outcomes of a three-year adaptation procedure (in terms of energy efficiency measures) were calculated in the transportation networks with 100% renewable wood supply from different raw-material procurement locations to manufacturing. Along with a considerable improvement in fleet adaptability, the indicator showed that regional transportation circumstances affect the system's energy efficiency. The adaptation of transportation fleets, for example, toward larger and heavier vehicles, may be advanced further with the use of this unique knowledge about the effects of supply areas. Additionally, the indication gives transportation business owners the ability to organize their cargoes and control their cars in the chosen region in the most energy-efficient manner.

Feroz Ahmed [33] green computing solutions, but some still require in-depth research, such as how to manage the thermal energy lost during processing with supercomputers or huge data centers. The improvement of the environment must be taken into account while designing hardware. Additionally, there are variations in strategies for decreasing energy loss; some concentrate primarily on the computational element, while others concentrate on doing it holistically. This is a crucial area where different methods diverge.

Young-SikJeong [34] 17 excellent pieces were selected for this issue after a thorough screening procedure. It publishes articles on a variety of topics, including experience reports, experiments involving the implementation and application of new theories, contributions to theoretical research that present new techniques, concepts, or analyses, and tutorials on cutting-edge cloud computing and big data technologies for upcoming smart cities.

Anna M. Walker [35] It is not necessary to design a new toolkit to evaluate the sustainability of CE activities in circular inter-firm networks; instead, appropriate SA techniques should be found in the body of existing research. By synthesizing the scholarly contributions to SA made over the previous few decades in the domains of IE and CSCM, this study represents a significant step in that direction. It is the first evaluation to specifically link these two areas to encourage the linked SA techniques to interact with one another.

NiloofarGholipour [36] Due to several advantages including automatically optimized resource management and contemporary service delivery models, cloud computing is being quickly accepted for managing IT services as a noteworthy option. Cloud service companies have lately debuted the container as a service and as an alternative to existing cloud services. Applications may execute and be deployed in isolated virtual spaces using containers, which share the same operating system kernel.

Additionally, containerization is used for running separated programs since it offers qualities like scalability, extremely portable features, and lightweight.For cloud providers, cutting down on energy use and CO2 emissions is a significant deal. Consolidation is advised as a crucial energy-conscious strategy in cloud data centers in this direction. For green computing in cloud data centers, autonomous virtual machine migration or container migration had already been proposed in the literature. However, this study suggests a novel technique for managing cloud resources based on a multi-criteria decision-making process that simultaneously makes use of a joint virtual machine and container migration strategy. The outcomes of simulations utilizing the Container Cloudsim simulator support the viability of the suggested strategy, showing substantial decreases in energy usage, SLA violation, and many migrations as compared to cutting-edge techniques.

Sarah Butt [37] To assess the IoT issues and Green IT solutions, this article suggests four critical research topics. A range of literature reviews that concentrate on the research topics put out for this study will also be offered. The IoT issues, Green IT characteristics, Green IT designs, and the process of putting Green designs into practice as a response to environmental concerns will be the main topics of the questions.The importance of this literature evaluation and the purpose of the research questions will aid in identifying the most popular ideas and suggestions for adopting green IT. This essay makes an effort to compile both recent and historical research papers to assess and contrast the top Green IT solutions. Additionally, it aims to show how to analyze a variety of pertinent ideas from many writers to choose the most

effective sustainable IoT designs. The optimal method of incorporating Green IT into daily life will be determined after doing a comparative study of all available options.

## 6. GREEN COMPUTING FOR SUSTAINABILITY

One of the key objectives of the modern era is the sustainability of communication technologies. It relates to an organization's social, economic, and environmental effects (service suppliers, administration, academia, enterprises,etc). Sustainability must take into account green computing. There is a connection between these two ideas. Sustainable is defined as "developing and investing in a technological infrastructure that fulfills the demands of today as well as the needs of today while preserving resources and saving money." Green is typically associated with energy efficiency and environmental friendliness. Sustainability is crucial to achieving successful outcomes, but Green IT is the initial step for all of these goals.[14][27][42].

## 7. ISSUES AND CHALLENGES OF GREEN COMPUTING

Data centers should be powered by renewable energy sources, electronic waste from outdated computing equipment should be reduced, and telecommuting and remote computer management should be encouraged to cut down on traffic emissions[30][41][43].One of the biggest issues is lowering the amount of energy that clouds use. Green computing generally means making the most effective use of computer resources while reducing the negative effects on the environment. Load balancing is a technique used in cloud computing to distribute workloads among various computer resources. The major goals of cloud load balancing are to maximize resource availability while minimizing expenses using document management systems. They essentially boost both performance and resource availability in the cloud. The energy use of data centers is directly correlated with the performance indicators. Consequently, effective load-balancing strategies also aid in making cloud networks energy efficient[21][45][ 46].

## 8. CONCLUSION AND FUTURE WORKS

The concept of "green computing" has gained traction during the past several years and is still doing so. Green computing entails making better use of previously available computing resources by putting cutting-edge concepts like green clouds into reality. It also involves designing, using, and disposing of computers in an environmentally friendly way. Instead of focusing primarily on financial incentives like cost-cutting, Cloud service providers must consume less electricity while considerably increasing the usage of renewable energy sources about green computing. Researchers may concentrate on improving the energy efficiency of data centers and cloud computing. Business organizations need to make more green initiatives. All interested parties must cooperate for a better future. If not, there will be conflict among humans.

Future research should look at how social value, business value, and consumer value are related. and how a sustainable IT strategy will affect each. These concepts seem to be complementary to one another. Many business executives, however, believe that they are in opposition to one another or, at the very least, that they might result in concessions that are not always in the best interests of the organization. To fully understand how a sustainable product might change the market IT services strategy, more research is required. Along with financial savings, there are other advantages. Are clients willing to pay for environmentally friendly company practices? Does sustainability factor into the development of a competitive edge for IT services? Finally, a plan for developing and implementing sustainable IT services has to be developed. Most likely, the integration is included in this model.

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# تطبيق الحوسبة الخضراء من أجل الاستدامة مراجعة للقضايا والتحديات في معالجة

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***الملخص***

*تشير "الحوسبة الخضراء" إلى الاستراتيجيات والإجراءات الخاصة بتصنيع موارد الكمبيوتر واستخدامها والتخلص منها فيما يعد بطريقة مسؤولة بيئيًا أو بطريقة ودية دون ضرر على البيئة والكائنات الحية، مع الحفاظ على الأداء العام للحوسبةوبالتالي الحفاظ على الأداء العام للحوسبة. يستلزم هذا الامر استخدام مواد أقل خطورة ، والحصول على أقصى استخدام ممكن من المنتج مع استخدام أقل قدر ممكن من الطاقة ، بالإضافة إلى جعل العناصر القديمة والقمامة أكثر قابلية لإعادة الاستخدام، وقابلة لإعادة التدوير ، وقابلة للتحلل. في هذا المضمار تبذل العديد من الشركات جهودًا لتقليل الآثار السلبية لأنشطتها على البيئة. مثلا اتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ (UNFCC) هي اتفاقية بيئية عالمية تهدف إلى الحفاظ على استقرار انبعاثات الغازات المسببةللاحتباس الحراري، عند مستوى من شأنه أن يوقف التدخل البشري الضار في البيئة. تنطوي التنمية المستدامة على نمو نظيف لا يعرض احتياجات الأجيال القادمة للخطر. بهذا تتحقق أهداف التنمية البشرية مع حماية النظم البيئية والموارد الطبيعية الضرورية للحضارة. في هذه الورقة البحثية تم التأكيد على أهمية الحوسبة الخضراء للتنمية المستدامة وتمت مراجعة العديد من الدراسات الحديثة المهمة في هذا الموضوع.*

***الكلمات الداله :***

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