Green Cloud Computing: A Literature Survey

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***Abstract*: -In today's world, companies are under increasing pressure to take care of the environment. As technology continues to advance, businesses are discovering new ways to reduce their carbon footprint and contribute to a more sustainable future. One of the solutions that have been gaining momentum in recent years is cloud computing. By moving data and applications to the cloud, companies can reduce their energy consumption, minimize waste, and contribute to a greener world.**

Cloud computing is a dynamic area of information and communication technologies (ICT) that brings new environmental challenges. Cloud computing technologies have a wide range of applications because they offer scalability, are reliable and trustworthy, and provide high performance at relatively low cost. The cloud computing revolution is reshaping modern networking and offers promising prospects for environmental protection as well as economic and technological benefits. These technologies have the potential to improve energy efficiency and reduce carbon footprint and (e-)waste. These characteristics can transform cloud computing into green cloud computing. In this review, we provide an overview of the key achievements of Green Cloud Computing. First, an overview of cloud computing is given. Then, recent studies and developments are summarized, and environmental issues are specifically addressed. Finally, future research directions and open problems related to green cloud computing are explained.

1. INTRODUCTION

The world is becoming increasingly digital, and as a result, our reliance on electronics has never been higher. However, with this growth in technology comes a significant environmental challenge: electronic waste, or e-waste. Every year, millions of tons of e-waste are generated globally, leading to toxic pollution and environmental degradation. Sustainable computing is a growing movement that seeks to address this issue by promoting environmentally friendly practices and solutions in the tech industry. From designing energy-efficient devices to implementing recycling programs, sustainable computing has the potential to transform e-waste into sustainable ecosystems. The world is becoming increasingly digital, and as a result, our reliance on electronics has never been higher. However, with this growth in technology comes a significant environmental challenge: electronic waste, or e-waste.

Every year, millions of tons of e-waste are generated globally, leading to toxic pollution and environmental degradation. Sustainable computing is a growing movement that seeks to address this issue by promoting environmentally friendly practices and solutions in the tech industry. From designing energy-efficient devices to implementing recycling programs, sustainable computing has the potential to transform e-waste into sustainable ecosystems.

The impact of e-waste is not limited to one area of the world. It affects both developed and developing countries alike. In some developing countries, e-waste is often dumped in landfills or burned, leading to severe pollution and health problems. In developed countries, there are often more regulations in place for e-waste disposal, but the sheer volume of e-waste generated can still lead to environmental degradation.

Figure 1 Green Computing

Sustainable computing offers a potential solution to this problem. The best solution for all of this is Green Cloud Computing.

2. INTRODUCTION OF GREEN CLOUD COMPUTING

Green cloud computing entails developing environmentally friendly cloud workloads and infrastructures, as well as collaborating with cloud or data centre providers who engaged in long-term sustainability. This isn't a simple task, but it'll

become more crucial as firms' workloads rise in size [1]. Green computing involves reducing the energy consumption of devices, minimizing electronic waste, and promoting sustainability in the technology industry.

With the growing concern over climate change, companies are increasingly looking for ways to reduce their carbon footprint and contribute to a more sustainable future. One of the ways businesses can accomplish this is using cloud computing.

Green cloud computing is a cloud computing strategy that aims to minimize the environmental impact of cloud-based infrastructures and applications. Green cloud computing has two main goals. The first is to reduce the overall energy consumption of cloud data centres and the workloads that run in them. The second is to source energy in clean and sustainable ways wherever possible, so that the energy that clouds do consume leaves a smaller carbon footprint [2]

Devising a green cloud computing strategy requires designing cloud workloads and architectures to be environmentally friendly, as well as choosing cloud or data centre providers with genuine commitments to sustainability. That's no simple feat, but it will become increasingly important for businesses that want to keep their clouds sustainable even as their workloads grow in scale [3].

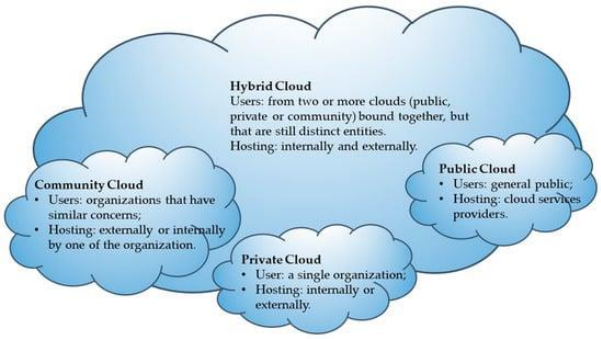

Figure2 Types of Cloud Computing

The reason of this paper is to overview the existing writing on green cloud computing and to recognize the key issues that have been inquired about and connected. The foremost vital commitments of cloud computing to environmental protection are recognized within the taking after segments. This paper does not display unused arrangements for green cloud computing. Instep, it highlights the interest and endeavors of analysts and society in an awfully vital zone: economical mechanical advancement. Scholarly literature is concerned with advancement and continuously presents the most recent disclosures and accomplishments within the investigated field.

3. DEVELOPMENT OF GREEN CLOUD COMPUTING

Green cloud computing is an emerging technology that uses energy-efficient practices in cloud computing [4]. It aims to reduce the carbon footprint of cloud computing while still providing the same level of computing power and resources [6]. Compared to traditional data centres, cloud computing is greener due to its energy efficiencies [5]. Green cloud computing offers several benefits, such as reduced power usage, lower carbon emissions, and cost savings. By adopting green cloud computing practices, organizations can contribute to environmental sustainability while still meeting their computing needs [4]. However, there are also some limitations and challenges to implementing green cloud computing, which need to be addressed to realize its full potential [6]. Cloud computing can be considered as a hierarchy of concepts, which comprises of several models. The first model is the Service Model [7] which further includes three models namely – software as a service, platform as a service and infrastructure as a service. Second is the Deployment model [7] which further comprises of public cloud, community cloud and hybrid cloud. According to National Institute of Standards and Technology (NIST) – "the major objective of cloud computing is to maximize the shared resources and at the same time the disadvantage is its high infrastructure cost and unnecessary power consumption."

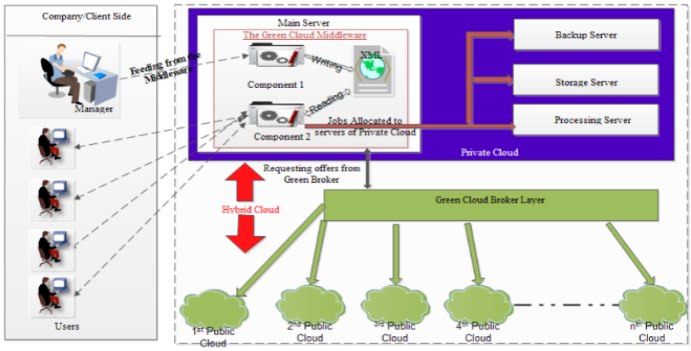

Figure 3 Shows About the Configuration of The Cloud System and Its Users.

Global warming has been a big concern of late, with high power consumption and CO2 emission acting as a catalyst to increase the same. The world has become highly protective about the environment with inputs from contributors such as – Greenpeace, Environmental Protection Agency (EPA) of the United States and the Climate Savers Computing Initiative to name a few. With the continuously increasing popularity and usage of cloud computing and the increasing awareness of the people across the globe towards the use of eco-friendly resources has forced the researchers to devise concepts towards an eco-friendly energy efficient flavour of cloud computing called green cloud computing. According to the previous works green cloud computing facilitates the reduction of power consumption and CO2 emission along with the reutilization of energy in an efficient way.

4. EXISTING WORK ON GREEN CLOUD DEVELOPMENT

Cloud uses thousands of datacentres in order to process the user queries and to run these data-centres bulk amount of power is used for cooling and other processes. Every year this power consumption is gradually increasing and green cloud computing endeavours to reduce the same thus playing a helpful role to curb these issues. There are various techniques and algorithms used to minimize this expenditure [9]. Among various avenues, one area of research focuses on reduction in energy consumption by computer servers [7], whereas the other lays stress on dynamic cluster server configuration [10,11] to reduce the total power consumption by balancing load and effectively utilizing only a subset of the resources at hand. Similarly Dynamic CPU clock frequency scaling [12,13] again incorporates some form of load balancing to save power during different load conditions. In addition to these, some more techniques are used to measure the power consumption in datacentres. The first one was developed by the Green Grid called Power Usage Effectiveness (PUE) metric to measure the effectiveness of data centres. PUE tells about the amount of extra power required for cooling IT equipment [8].

According to Wikipedia "PUE is a measure of how efficiently a computer datacentre uses its power "The range of PUE is varies from 1.0 to infinity. If the value of PUE approaching 1.0 it means efficiency is 100% and full power is used by IT equipment's. In recent years some companies achieved low number of necessary servers. If the Nn> No then, choose server in OFF state, signal them to restart and if Nn< No choose server in ON state and signal them to shut down. Fumiko Satoh et al., [18] also focus on reducing the usage of energy in data centres. But for the future energy management they develop an energy management System for cloud using sensor management function with an optimized VM allocation tool. This system will help to reduce the energy consumption in multiple data centres and results shows that it will save 30% of energy. This system also used to reduce the energy in carbon emissions.

Table 1 Efficiency formula chart

Metric	Explanation	Formula
Power usage Effectivenes (PUE)	It is the fraction of total energy consumed by the service of a data centre to the total energy consumed by IT equipments.	$PUE = \frac{\text{Total facility energy}}{\text{IT Equipment energy}}$
Carbon Usage Effectiveness (CUE)	It is a calculation of green house gases (CO_2, CH_4) release in atmosphere by the data centre	$CUE = \frac{(\text{Total } CO_2 \text{ emission from total energy used for service of data centre})}{\text{Total energy consume by IT equipment}}$
Water Usage Effectiveness (WUE)	It is calculation of yearly water used by data centre like for cooling, energy Production.	$WUE = \frac{\text{Annual usage of water}}{\text{Total energy used IT equipment}}$
Energy Reuse Factor (ERF)	It calculates the reusable energy Like hydro power, solar power etc used by data center.	$ERF = \frac{\text{used of reused energy}}{\text{Total energy used IT equipment}}$
Energy Reuse Effectiveness (ERE)	It is a parameter for measuring the profit of reuse energy from a data centre.	$ERE = \frac{\text{Total energy - reused energy}}{\text{Total energy used IT equipment}}$
Data centre Infrastructure Efficiency (DCiE)	This factor is used to calculate The energy efficiency of a data Centre.	$DCiE = \frac{\text{Total IT equipment power}}{\text{Total facility power}} * 100\%$
Data Centre Productivity (DCP)	It calculates the amount of useful work done by data centre.	$DCP = \frac{\text{Total Useful work}}{\text{Total resource used to do this work}}$
Compute Power Efficiency (CPE)	It determines the total amount of power is truly used for computing.	$CPE = \frac{\text{IT equipment utilization energy}}{PUE}$
Green Energy coefficient (GEC)	It measure the amount of green energy used to provide services to data centre.	$GEC = \frac{\text{Green energy consumed}}{\text{total energy consumed}}$
Space, Wattage and Performance (SWaP)	It is used for work out the space and energy required by the data centre.	$SWaP = \frac{\text{Performance}}{\text{Space} * \text{power}}$
DataCentre Energy Productivity (DCeP)	It calculates the quantity of useful work done by data centre as compare to total energy consumed to make this work.	$DCeP = \frac{\text{Total Useful work done}}{\text{Total energy used to do this work}}$

5. IMPLEMENTATION OF GREEN CLOUD COMPUTING

Green cloud computing refers to the use of environmentally sustainable practices in cloud computing. Here are some steps that can be taken to implement green cloud computing:

1. **Use energy-efficient hardware:** The first step towards green cloud computing is to use energy-efficient hardware. This can be achieved by using servers with low power consumption, LED monitors, and energy-efficient cooling systems.

2. **Virtualization:** Virtualization is the process of creating a virtual version of an operating system, server, storage device, or network. It reduces the number of physical servers required and saves energy.

3. **Renewable energy:** Renewable energy sources like solar, wind, and hydropower can be used to power the data centres. This will reduce the carbon footprint of the cloud computing infrastructure.

4. **Energy management tools:** Energy management tools can be used to monitor and manage energy consumption in data centres. This will help in identifying areas where energy can be saved.

5**. Cloud-based applications:** Cloud-based applications can help in reducing energy consumption as they do not require high-end hardware to run. Moreover, they can be accessed from anywhere, reducing the need for travel.

6**. Recycling and waste management:** Proper recycling and waste management practices can be implemented to reduce the environmental impact of cloud computing. This includes recycling of old hardware, using biodegradable materials, and proper disposal of electronic waste.

7. **Dynamic Voltage Frequency Scaling (DVFS):** It's a strategy for lowering processor power and energy usage that's combined with frequency scaling (a technique where dynamic control of the voltage and frequency is adopted). The DVFS minimizes data centre energy usage and maximizes resource use. As a result, adopting Green Cloud Computing makes it possible to lessen one's carbon footprint.

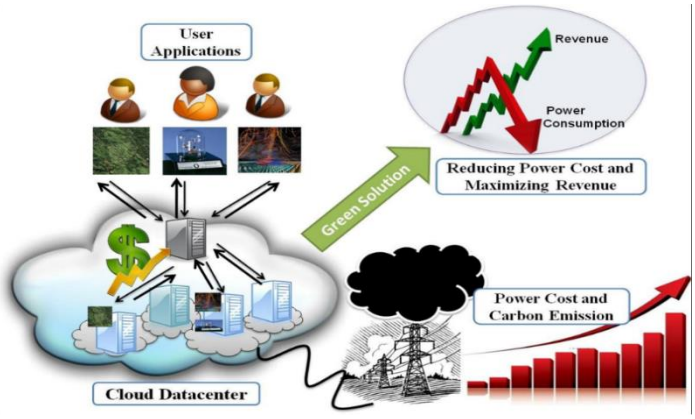

Figure 4Economy and Cloud Datacenter

6. IS CLOUD INFRASTRUCTURE 'GREEN'?

Today, all the major public cloud providers have made significant commitments to environmental sustainability. So, by the way, many colocation companies sell data centre space (and sometimes server infrastructure) that companies can use to build their own or private clouds. hybrid clouds.

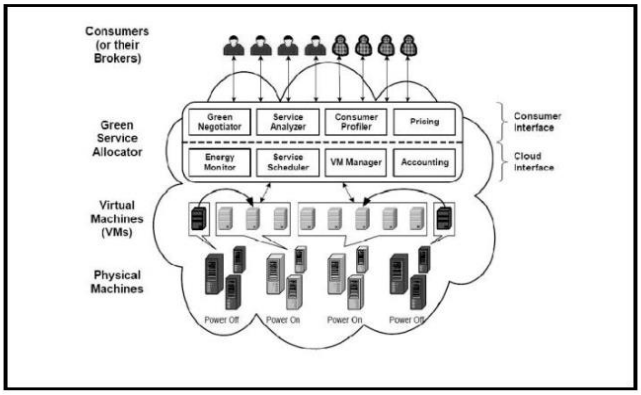

Figure 5Green Cloud Architectural Elements

However, that doesn't mean simply choosing to run workloads in the cloud or the data centre promises to be the "green" or "carbon neutral" equivalent of green cloud computing. It is important to consider exactly how well your supplier is delivering on their sustainability promise. Most data center and cloud companies use a combination of two approaches to pursue green cloud initiatives:

Sustainable energy delivery: Companies using Use renewable energy sources, such as wind and solar, to avoid emissions from "dirty" energy.

Carbon Offset: They purchase carbon offsets to offset the fossil fuels their data centres consume.

Historically, most cloud and hosting companies have relied more on carbon offsets than on sustainable energy delivery. The three big clouds – Microsoft Azure, Google Cloud, and AWS – have all committed to only source energy from "clean" sources by the end of the decade, but in the meantime, their ability to claim carbon neutrality depends heavily on their ability to buy carbon. offset. If you believe – as some do – that carbon offsetting matters in many ways, then you may want to look for a data centre or cloud provider that has a recipe for achieving infrastructure. Green floors rely more on clean energy supplies than on compensating. It's also important to note that nuclear power is one of those energy sources that most cloud providers classify as "clean" or "renewable" - although they usually don't talk much about it. this topic as well as highlighting their investments in solar and wind farms. In this sense, your opinion of what counts as a "green" cloud may depend on the extent to which you consider nuclear power generation to be green.

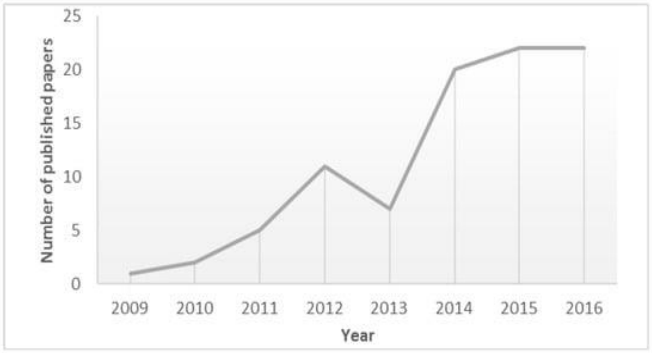

Figure 6 Distribution of surveys over years

7. GREEN CLOUD COMPUTING FUTURE, STATUS AND TRENDS

Intrigued in examining the impact of cloud computing on the environment is on the rise due to the consideration gotten by green computing from the computing community. It was a response to the report distributed by Gartner, which evaluated that the worldwide ICT industry accounted for roughly 2% of worldwide CO2. In 2009, Liu et al. displayed Green Cloud a modern design which points to diminish information center control utilization. Be that as it may, the intrigued in finding strategies to diminish vitality utilization in information centers is indeed more seasoned and has heightens since 2009. These considers were exceptionally critical for green cloud computing advancement. Green information centers—where vitality effectiveness is maximized and CO2 outflows and e-waste are minimized, not as it were for ICT hardware, but for all natural viewpoints (building, lightning, cooling, etc.)—are the premise for real and future green cloud computing. Green computing isn't restricted to the vitality utilization of computer gadgets. It incorporates the vitality utilization of systems or cooling hardware, but too other natural issues, such as CO2 outflows, (e-)waste administration, and utilization of common assets. In this setting, researchers' interface has been isolated within the subfield of green computing.

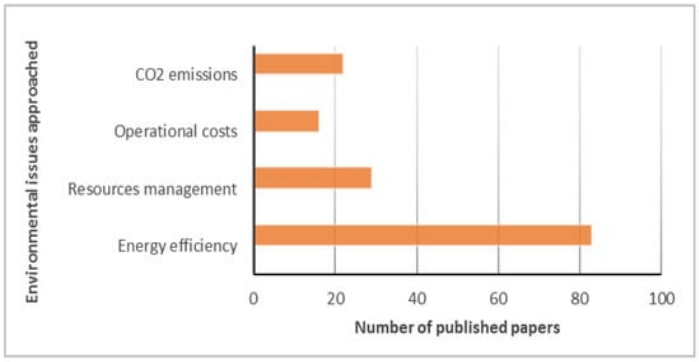

Figure 7. Distribution of surveys on environmental issues between 2009 and 2016

They started by analyzing the relationship between "sustainability" and "cloud computing". The advancement of this inquire about was determined by the increment in intrigued within the environment and by the expanded utilize of cloud computing. Figure 2 outlines the developing intrigued in green cloud computing within the scholarly writing between 2009 and 2016, with the single special case of 2013.

In the papers on green cloud computing, the authors have proposed new methods and models to optimize resource management or to reduce energy consumption. Algorithms are presented in a substantial number of articles. Other aspects such as metrics, general studies of negative influences on the environment, and the involvement of providers in environmental protection are included in the general issues category.Efficient resource management will improve cloud computing performance by reducing energy consumption, e-waste, and costs. In green cloud computing, resource management means using heterogeneous and geographically distributed resources to meet clients' requests with the minimum negative effect on the environment. Fortunately, some factors which benefit cloud computing providers also bring benefits for the environment. For example, reducing energy consumption will cut providers' costs, but will also result in reduced CO2 emissions.

Figure 8.Distribution on categories of green cloud computing surveys.

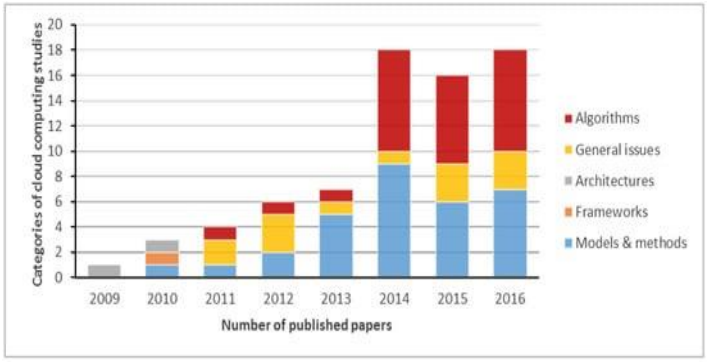

Figure 8 presents the five categories of green cloud computing studies (models and methods, architectures, frameworks, algorithms, and general issues) identified in the literature review between 2009 and 2016.

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8. APPLICATIONS OF GREEN CLOUD COMPUTING

Widely green computing is used in the following areas in organizations:

- Management of energy in Data Centres
- Green Wireless Network
- Green Parallel Computing with Big Data Network
- Green computing with an algorithm

9. PROS AND CONS

Green cloud computing has both advantages and disadvantages. [24][25]

Advantages of Green Cloud Computing:

1. Energy savings: green cloud computing uses energy-efficient hardware and software, which leads to reduced energy consumption and cost savings.
2. Cost savings: green cloud computing reduces the cost of hardware, software, maintenance, and electricity bills.
3. Recycling process: green cloud computing supports recycling and the use of renewable energy, which makes it more sustainable.
4. Brand strengthening green cloud computing helps companies to build a better reputation among customers who value environmentally friendly practices.
5. Less pollution: green cloud computing reduces carbon emissions and helps protect the environment.
6. GHG emission: green cloud computing helps in reducing greenhouse gas emissions.

Disadvantages of Green Cloud Computing:

1. Initial implementation costs: One of the main drawbacks of green cloud computing is the high initial investment required for setting up the infrastructure.
2. The disparity in the level of understanding across various companies: Companies may have different levels of understanding and commitment towards green cloud computing, which can lead to disparities in implementation and impact.
3. Technical limitations: The technology used in green cloud computing may have technical limitations that can affect its performance.
4. Security concerns: green cloud computing may have security concerns, such as data privacy and protection, which need to be addressed.

In summary, while green cloud computing has several advantages, it also has some disadvantages that need to be taken into consideration before implementing it.

10. CONCLUSION

Designing a green cloud strategy requires designing eco-friendly cloud workloads and architectures and choosing a data center or cloud provider with a real commitment to sustainability. That's no small feat, but it will become increasingly important for businesses looking to future-proof their clouds, even as their workloads grow. The goal of green cloud architecture is to reduce data center power consumption. The main advantage of the green cloud computing architecture is that it ensures real-time performance while reducing the power consumption of the IDC (internet data center). The concept of “going green” has been around since 1992. Despite its limitations, green cloud computing is a concept studied to protect our environment. The concept changes and evolves, but what is needed is to reduce carbon emissions in the environment.

This idea is to save both money and the environment. The risk to human life due to e-waste disposal is also expected to be significantly reduced. Together, cloud computing and green computing will help businesses reduce their carbon footprint while providing a productive work environment. Today, green cloud computing and environmental sustainability are essential.

At the same time, we shed light on the recent work that has been done in the field of green cloud computing for a healthier and greener environment. Therefore, we have launched a comparative study in the field of green cloud computing. There are many possible directions for later work. In this article, we tackle the problem of how to efficiently fetch results from the cloud so that all the features mentioned in the article can be realized. In addition, we can implement a method to automate Blue Cloud Manager making all service-related decisions.

Table 1 - Global statistics on total Cloud Energy consumption

	Electricity Consumed in 2007 (Billion KWH)	Electricity Consumption forecasted for 2020 (Billion KWH)	Electricity relevant Carbon Omissions by 2020 (MtCO2e)
Data Centers	330	1012.02	533
Telecom	293	951.72	501
Total Cloud	**623**	**1963.74**	**1034**

11. ACKNOWLEDGEMENTS

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