Green Cloud Computing Navigating Towards Sustainable Horizons: A Comprehensive Review

Rakesh Puttannavar [1]
Alvas Institute of Engineering and technology
Department of Computer Science and Engineering
rakuap04@gmail.com [1]

Ramit Santhosh Shetty [2]
Alvas Institute of Engineering and technology
Department of Computer Science and Engineering
ramitshetty100@gmail.com [2]

Dr Aslam B Nandyal [3]
Alvas Institute of Engineering and technology
Department of Computer Science and Engineering
aslam@aiet.org.in [3]

ABSTRACT---An ongoing transition to green energy solutions is necessary to prevent environmental catastrophes in light of the critical convergence of the IT industry. In addition to exploring the topic of green cloud computing, this study looks at data canters, who are well-known energy consumers. It looks at the requirements, limitations, and patterns influencing environmentally friendly change through an extensive assessment of the literature. The study shows how closely cloud computing, a technology that offers reliability but also presents environmental difficulties, is tied to the use of green energy. the development of IT towards its future. Flexibility serves as the cornerstone of contemporary green cloud computing, and 20 demonstrates its successes in reducing waste, using less energy, and leaving a smaller carbon imprint. As the world's temperatures rise, businesses must adopt the concepts presented in this report, which also highlights the green cloud. Apart from emphasizing implementation concerns, the paper offers insights on obtaining and implementing green cloud computing and lays the groundwork for an IT environment that is more environmentally conscious and sustainable.

Key words: Green cloud computing, Cloud computing, Energy efficiency.

I. INTRODUCTION

Due to the fact that users can access computer systems remotely and without purchasing additional gear, the emergence of the cloud as a computing platform has brought about yet another type of change in the field of information technology. Technology based on the cloud 99 has shown over the past few years that it may be helpful in a variety of industries, but additional problems relating to increased energy usage and data expansion have also surfaced. Since web users may now connect online without the need for additional equipment, there are a lot more environmental dangers because this has changed the IT environment and resulted in data centers emitting notably more carbon dioxide. Despite its many benefits, cloud computing nevertheless exacerbates issues related to energy consumption and data growth. Others worry about the environmental risk posed by data centers' massive carbon emissions from switching from conventional architecture to cloud computing. It is anticipated that GIt will generate roughly 43 GW of power in 2013. In addition, the expansion of corporate intranet accessibility and broadband Internet connectivity is making it possible to introduce new network services [2].

The Internet of Things (IoT) introduces a new dimension to the environmental impact of technology that extends beyond cloud computing. The term "internet of things" (IoT) describes the collection of physical objects that have sensors and software integrated into them that enable communication and interaction. The World Wide Web of Things along with cloud computing are combining to create a trend that is driving increased demand for data centers. It raises the cost of energy to a greater extent. While network-based computers and storage have added to the range of services available these days, email and TMI have been available for a while.

A service provider may deliver a sizable number of high speed computing units along with large capacity storage facilities under the cloud-based computing model, which may then be divided among the final customers upon request [5-7]. Many software and hardware developers are increasingly more aware of the sustainability for both themselves and their consumers. The evaluation of the environmental effects of ICTs (Information and Communication Technologies) has become imperative due to the dramatic increase in energy demand over the past few decades. The goal of this review is sustainability, with the hope of encouraging environmentally friendly and cost-effective ICTs that can drastically lessen the negative effects of information and communication technologies on the natural world. Environmental informatics, environmental informatics, ethical computing, green computing, and green ICTs are just a few of the new terms that have emerged in the field of ICTs and environmentally related issues.

However, it has recently been demonstrated that this technology, particularly among technology for communication and information (ICTs), offers a number of environmental benefits. Green practices are provided by climbing companies, but government agencies are pushing hard for effective management of environmental impacts. Hilty et al. [1] state that consideration should be given to the current and potential implications of technology for communication and information on the environment when making decisions regarding sustainable development. As an illustration, how we prioritize interpersonal connections and social interactions in today's world and how we perceive these two factors are both important. Given that data centres are the foundation of cloud computing, there is an unexpected correlation between the growth of environmentally friendly cloud computing technologies and the establishment of 333 environmentally friendly data centers. Making the switch to sustainable computing concepts is necessary since one of the numerous problems impeding our progress toward a greener planet is the massive energy consumption of data centers.

This show the enormous potential of data centers and represent an incredible percentage of all resources. These server farms comprise the cloud. The results show that switching to cloud computing, which would do away with the requirement for email, productivity software, and CRM software, could potentially save all US corporate users up to 87% on their primary energy footprint[8]. One study suggests that if energy-efficient versions of ICTs were created, they would contribute more to global carbon dioxide emissions. Researchers created modeling tools to estimate the possible energy savings from relocating local PCs and web applications to cloud server farms. The results show a considerable drop in the energy footprint of numerous software programs, including email, CRM software, and business software. The potential environmental benefits of cloud computing become more apparent when data centers follow green computing standards.

Hot aisle temperatures in data centers are usually measured between 80 and 115 degrees Fahrenheit..

Despite the seemingly low recorded temperature, data centers generally prefer lower temperatures[9], hence it's critical to utilize the heat generated efficiently.With an emphasis on important issues, breakthroughs, challenges, and possible directions for future research, this article reviews the literature that has already been published on green cloud computing. The study provides in-depth information on both academic as well as non-academic learning in the paper, but it makes no recommendations for alternatives. It is possible to gain a lasting understanding of technology growth by integrating academic material with non-academic viewpoints from bloggers, journalists, NGOs, human rights advocates, and regular people. This study is divided into 25 sections that cover non-academic studies from various sources, research methods, the journey of green computing through cloud computing, a summary of cloud computing, current achievements in academic literature, and potential areas for future research. Green cloud computing will be crucial to the growth of the IT sector in the future.

II. Literature Review

The way consumers and organizations access and use computing resources has altered as result of the cloud computing industry's explosive growth. However, there were substantial environmental costs involved with this enormous investment, mostly because of the energy usage and carbon emissions of conventional cloud data centers. The idea of "green cloud computing" arose in response to these worries, with the goal of minimizing environmental effect while preserving operational efficiency and scalability. The literature review in this study covers several studies on green cloud computing, covering key findings, techniques, and developments in the subject. In order to give a thorough and thorough assessment of the state-of-the-art in green cloud computing, and to provide fresh research avenues for the future, the report incorporates the findings of previous studies [12].

This paper's literature review comprises an extensive assessment of works on green cloud computing, with a particular emphasis on topics like environmental effect mitigation, sustainability, as well as carbon . The report provides suggestions for future studies and procedures that complement the integrated perspective by merging the findings and analysis from earlier investigations[16].In the literature on green cloud computing, creating energy-efficient services is a key concern Researchers and experts in the field have looked into a number of tactics to boost data center energy efficiency, including server virtualization, dynamic resource allocation, and the integration of Even with substantial advancements, green cloud computing's full potential is still untapped. Complicated limitations combined with financial, legal, and technical constraints make widespread adoption difficult. It will take multidisciplinary cooperation, inventiveness, and steadfast dedication from stakeholders in industry, government, and academia to address these issues. Research focusing on the future of green cloud computing enhancements includes creating frameworks for legislation, optimization methods, and energy-efficient technology. obtaining the use of renewable energy sources. The goal of these initiatives is to lessen the cloud computing industry's carbon footprint without sacrificing effectiveness or dependability.

The usage of data in cloud settings has been included in the efforts to lower carbon emissions. Measures to improve storage efficiency and lower energy usage have been suggested, including data compression, data diversification, and intelligent data transport. By using these techniques, cloud service providers can reduce their transformative instrument and maximize their resources. It is feasible for interested parties to build a cloud computing infrastructure that positively affects the environment.

The full potential of green cloud computing remains unrealized despite significant development. Widespread adoption is hampered by financial, legal, and technical limitations as well as complicated restrictions. It will take multidisciplinary cooperation, creativity, and sustained dedication from government, business, and academic stakeholders to address these issues.

Future-focused research on green cloud computing enhancements includes the creation of energy-efficient technology, optimization algorithms, and legislative frameworks. Achieving decent environmental outcomes in the context of cloud computing also requires increasing knowledge, advocating for, and putting into effect practice-changing devotion to environmental sustainability.

To summarise, adopting green cloud computing presents a significant chance to mitigate the adverse societal effects of cloud services and optimise their cost-effectiveness as a transformative instrument. It is possible for stakeholders to successfully construct a cloud computing infrastructure that supports sustainability and is cleaner by combining technological advancements, regulation, and cooperative working practices. Numerous initiatives

are under progress, and we have new ones in the works that we could launch. Advocacy, investment, and research will aid in this endeavor. This must be carried out during the upcoming years. The literature review in this work provides a critical evaluation of the present state of the knowledge regarding energy consumption in cloud computing, focusing on three primary areas: processor, storage, and transport components. The paper considers possibilities and challenges in achieving energy conservation in cloud computing channels but also highlighting the existence of a number of intriguing ways to lessen the negative environmental effects of energy use[21].

Only energy-efficient data centers are reviewed in this research. Among other innovative practices in the field of information systems, methods for cloud resource virtualization and power consumption reduction are examined. By analyzing the available research, recommendations for the development and administration of green cloud computing—with a focus on energy-efficient data centers—could be made[24].Four key pillars emerged from our thorough examination of green cloud computing: low operational costs, resource efficiency, energy efficiency, and environmental friendliness. As a result, this literature review is a useful tool that offers a summary and critical analysis of the developments, difficulties, and inventions in green cloud computing.

III.APPLICATIONS OF GREEN CLOUD COMPUTING

A. The "green" things' internet

The Internet of Things (IoT) facilitates monitoring and decision-making by connecting intelligent devices in a variety of networks. The growing number of IoT devices indicates the state of the cloud computing infrastructure. Because these Internet of Things (IoT) devices need to be mobile and have minimal latency, edge computing is becoming quite popular for real-time applications. One idea is fog computing, a type of distributed system that connects devices throughout the network with different degrees of processing power. Regardless of which device is hosting centralized cloud architecture, this paradigm enables low-latency experience and promotes communication. The primary goal of green computing is to minimize energy consumption and computer resource usage while maintaining a pleasant user experience. Green computing makes use of a computer system's energy resources to enable eco-friendly energy use among other things.

Several technology domains are used in green computing:Several technology domains are used in green computing:

• Autonomous vehicles: However, in order for the makers to keep an eye on their utilization level and respond to important maintenance alerts, autonomous vehicles must stay in close contact with them. It would be pleasant to observe that edge computing facilitates data exchange and transfer amongst autonomous vehicles more easily than in the past. They can achieve this by lowering the energy used by sensors unique to each device in cars equipped with autonomous driving features.
• Smart cities: Officials use sensor data on traffic, infrastructure, and household appliances to address problems that metropolitan areas face. Such gadgets ought to react more quickly and autonomously, reducing the need for energy.environmentally responsible approach.
• Industries: By introducing a cutting-edge substitute, Internet of Things edge computing, to the oil exploration domain, environmental data comprising factors like temperature, pressure, and seismic activity can be obtained. Because edge computing is the most distributed, there would be a decrease in the amount of energy needed throughout manufacturing.

B. Green Distributed Computing in the Big Data Environment

While large information systems use algorithms with parallelism 16 for data processing, distributed databases are more frequently used for data structures.
The task of analytics is one that can be completed. Numerous paths to the platform computer can be examined using parallel translation algorithms. There will be noticeable differences in the environmental aspects of energy and electricity usage.

The majority of study has been on general computing metrics, like the improvement in computer performance resulting from the parallel processing methodology and the computing nodes' efficiency when the parallel computing approach is applied. By investigating how to search for green indications for enormous data items as the very instrumentation to try out various sorts of implementation, we may immediately put these concepts into effect.

C. Sustainable Medical Care

IT data center virtualization based on information technology. Devise is the top priority, and every company keeps this in mind. Choose eco-friendly medical treatment. Even yet, the primary objective is usually to reduce expenses.One common trait of virtualization is its adaptability, which is the primary element driving advancements in IT.the most crucial element. It is clear that the renewable energy source offers both large and low energy savings. The decrease in software and hardware, however, is substantial.

• Utilizing Electronic Health Records (EHRs). Healthcare practitioners can monitor, trace, and control healthcare delivery within an organization by using electronic medical records (EMRs). As predicted, EMRs can achieve this by reducing carbon dioxide emissions. The responders acknowledged that maximizing their productivity was made possible by the EMR. to avoid using the many tons of paper that are needed annually for medical records. We are so obliged to draw the conclusion that there is a net positive influence on the environment.

IV. Obstacles and Potential Research Areas

While some researchers will succeed, others won't. In this extremely challenging field of research, you can either become well-known or remain an untold tale. This indicates that, even in modest ways, you are making a difference and are trying your best to help. We eventually win over the youth and the community at large, sharing in the victory of liberation.The great majority of research studies concentrated on cloud computing's information security and level of service excellence. Enforcing environmental protection standards strictly is one thing; customer happiness with quality is another. When designing green clouds, we can find two kinds of obstacles: non-technical and technological. Immersion in a foreign language on a daily basis improves speaking and listening abilities. The virtualization techniques and thermally sound design patterns provide the foundation of green cloud computing technology.

An integral part of green cloud computing is software design. Resource management and energy efficiency apps have a lot of potential. It is essential that information be exchanged between software components accurately and efficiently. Our types need to be flexible, able to adjust to changing needs and efficiently provide resources to the server load. Our biggest problems are reducing energy usage, scheduling tasks and controlling costs, and allocating resources and energy continuously. The AVM allocation technique becomes viable for reducing total costs and energy consumption. The creation of a profitable company Workload migration between machines and VMM migration between data centers located in geographically separated areas may serve as the foundation for initiatives. Large concentrations of processing power might be concentrated in green cloud data centers, which could help mitigate the problem of environmental contamination. The difficulties of increasing virtual machine sizes without sacrificing energy consumption and the workload allocation across power-efficient data centers (using presumably renewable energy sources) are just two of the numerous unanswered issues. Moreover, a physical server is canceled in addition to improving processing capacity.

Plans for strategy and internal management guidelines. There are two issues in this instance: first, local rules vary, and second, there is no internationally accepted cloud legislation. Some WEFs have developed and put into effect strict regulations through regular audits and inspections. Many are liberal; they either rarely and without the required constraint, or they follow the rules nonexistently. The expense of green cloud computing is another non-technical issue. One reason for the increase in rates for cloud service providers is the transfer of this scope to the clients. Still, even non-technical folks may understand the issue of renewable energy.

V. CONCLUSION

In the end, the advent of green cloud computing seems to be a noteworthy advancement that highlights the issue of environmental responsibility in the digital era. We have concentrated on five important subjects using a more thorough literature analysis: engineering for carbon neutrality, measures to limit emissions, carbon-neutral infrastructure, and the role of law in this field. Additionally, we have looked at applications of green cloud computing in many different sectors, such as environmental monitoring, smart cities, healthcare, agriculture, and renewable energy integration. The scope and complexity of the proof of concept applications demonstrate how adaptable and quick Green Cloud Technology is to solve practical issues while protecting the environment and building resilience.

Thus, accelerating passive green cloud computing is the aim of future research initiatives. They cover the creation of effective power-saving methods, the best algorithms, eco-friendly data-recording methods, and sustainability-promoting legislative

frameworks. A large part of implementing this sustainable plan includes striving to accomplish the objectives of increasing awareness and placing a strong emphasis on education, as well as advocating for an environmental responsibility culture within the cloud computing community.

To put it succinctly, green cloud computing holds immense promise as a game-changing component in the creation of new digital technologies and a broader environmental sustainability. The stakeholders can therefore move toward a more resilient and environmentally friendly future by enacting new laws, implementing policy changes, Despite its slow rise through continued research, action, and investment, the concept of green cloud computing—which has the potential to be a big digital change—needs to be safeguarded for future generations.

VI. REFERENCES

[1] Hilty, M.L.; Arnfalk, P.; Erdmann, L.; Goodman, J.; Lehmann, M.; Wager, A.P. The relevance of information and communication technologies for environmental sustainability—A prospective simulation study.Environ. Model. Softw. 2006, 21, 1618–1629. [CrossRef]

[2] Cisco. (2009). Cisco visual networking index: Forecast and methodology, 2009–2014. White paper. [Online]. Available: http://www.cisco.com.

[3] GeSI. GeSI SMARTer 2020: The Role of ICT in Driving a Sustainable Future. 2013. Available online:http://gesi.org/SMARTer2020 (accessed on 2 November 2016).

[4] Hayes, B. (2008). Cloud computing.

[5] Open Cloud Manifesto. [Online]. Available:http://www.opencloudmanifesto.org/

[6] Koomey, J. Growth in Data Center Electricity Use 2005 to 2010. 2011. Available online:http://www.analyticspress.com/datacenters.html (accessed on 12 June 2016).

[7] Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., ... & Zaharia, M. (2010). A view of cloud computing. Communications of the ACM, 53(4), 50-58.

[8] Masanet, E.; Shehabi, A.; Ramakrishnan, L.; Liang, J.; Ma, X.; Walker, B.; Hendrix, V.; Mantha, P.The Energy Efficiency Potential of Cloud-Based Software: A U.S. Case Study. 2013.Availableonline:https://www.osti.gov/scitech/servlets/purl/1171159 (accessed on 12 January 2017).

[9] X. Yu, Y. Ma and J. Li, "Analysis and Research on Green Cloud Computing," 2018 2nd IEEE Advanced Information Management,Communicates,Electronic and Automation Control Conference (IMCEC), 2018,pp.521524,doi:10.1109/IMCEC.2018.8469521.

[10] Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., ... & Zaharia, M. (2010). A view of cloud computing. Communications of the ACM, 53(4), 50-58.

[11] Kavya Yadav, Dr. Manjot Kaur Bhatia "Analysis Report on Green Cloud Computing: A Report" International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538

[12] "A Survey of Green Cloud Computing: Models and Future Directions" by Anant R. Jadhav and Sanjay L. Nalbalwar (2015)

[13] Abhay Verma,Vinay Verma "Comparative Study of Cloud Computing and Edge Computing: Three Level Architecture Models and Security Challenges" International Journal of Distributed and Cloud Computing 9 (1) 2021, 13-17

[14] Gamsiz, M., & Özer, A. H. (2021). An energy-aware combinatorial virtual machine allocation and placement model for green cloud computing. IEEE Access, 9, 18625-18648.

[15] Gopi, R., Suganthi, S. T., Rajadevi, R., Johnpaul, P., Bacanin, N., & Kannimuthu, S. (2021). An Enhanced Green Cloud Based Queue Management (GCQM) System to Optimize Energy Consumption in Mobile Edge Computing. Wireless Personal Communications, 117(4), 3397-3419.

[16 "Green Cloud Computing: A Review on Green IT Areas for Cloud Computing" by Sonali Agarwal, Deepali Virmani, and Sonali Vyas (2013)

[17] Alyouzbaki, Y. A. G., & Al-Rawi, M. F. (2021). Novel load balancing approach based on

ant colony optimization technique in cloud computing. Bulletin of Electrical Engineering and Informatics, 10(4), 2320-2326.

[18] Singh, J. (2021). Energy consumption analysis and proposed power-aware scheduling algorithm in cloud computing. In Intelligent Computing and Applications (pp. 193-201). Springer, Singapore.

[19] Kansal, A., Zhao, F., Liu, J., Kothari, N., & Bhattacharya, A. A. (2010, June). Virtual machine power metering and provisioning. In Proceedings of the 1st ACM symposium on Cloud computing

[20] Jung, G., Hiltunen, M. A., Joshi, K. R., Schlichting, R. D., & Pu, C. (2010, June). Mistral: Dynamically managing power, performance, and adaptation cost in cloud infrastructures. In 2010 IEEE 30th International Conference on Distributed Computing Systems IEEE.

[21]"Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport" by Rajkumar Buyya, Young Choon Lee, and Xingchen Chu (2014)

[22] Necula, S. C. (2014). Implementing the main functionalities required by semantic search in decision-support systems. International Journal of Computers Communications & Control, 7(5), 907-915.

[23] Thakur, S., & Chaurasia, A. (2016, January). Towards Green Cloud Computing: Impact of carbon footprint on environment. In 2016 6th international conference-cloud system and big data engineering IEEE.

[24] "A Review on Green Cloud Computing: Virtualization Techniques for Energy Efficient Data Centers" by S. Suganya and R. Bhuvaneswaran (2014)

[25] Mridul Wadhwa, Approv Goel, Tanupriya Choudhury, Ved P Mishra, ”Green Cloud Computing - A Greener Approach To IT”, 2019 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE).

[26] Surendran.R, Tamilvizhi.T, ”How to Improve the Re- source Utilization in Cloud Data Center?”, 2018 Inter- national Conference on Innovation and Intelligence for Informatics, Computing, and Technologies (3ICT).

[27] Sheikh, R. A., & Lanjewar, U. A. (2010). Green computing-embrace a secure future. International Journal of Computer Applications.

[28] Masdari, M., & Zangakani, M. (2019). Green cloud computing using proactive virtual machine placement: challenges and issues. Journal of Grid Computing.

[29] Gavaskar, S., Anisha, A., Renit, C., & Shiney, T. S. (2016, April). Mobile apps for Green Cloud Computing performance measure. In 2016 International Conference on Energy Efficient Technologies for Sustainability (ICEETS)

[30] Mr. Nitin S. More,Dr. Rajesh B. Ingle, ”Challenges in Green Computing for Energy Saving Techniques”, 2017 International Conference on Emerging Trends Innovation in ICT (ICEI).

[31] Wang, D. (2008, December). Meeting green computing challenges. In 2008 10th Electronics Packaging Technology Conference IEEE.

[32] Ruth Barba-Vera, Marco Vinicio Ramos Valencia, Ligia Maricela Niama Rivera “INFORMATION AND COMMUNICATION TECHNOLOGIES: HIGH IMPACTS OF GREEN CLOUD COMPUTING”/ Eur. Chem. Bull. 2023,12(4), 2392-2407

[33]Tariq Rahim Soomro, Muhammad Sarwar “Green Computing: From Current to Future Trends”/World Academy of Science, Engineering and Technology Vol:6 2012-03-20

[34] The Green Web Foundation. The Green Hosting Directory, as used by the apps. Internet Source:https://www.thegreenwebfoundation.org/directory/

[35]Nader Nada, Abusfian Elgelany “Green Technology, Cloud Computing and Data Centers: the Need for Integrated Energy Efficiency Framework and Effective Metric”/ (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 5, No. 5, 2014

[36]Greengeeks. Internet Source: https://www.greengeeks.com/affiliates/track.php?affiliate=divivion

[37]MaarufAli1andMahdiH.Miraz,“Recent Advances in Cloud Computing Applications and Services”/ at: https://www.researchgate.net/publication/260417956

[38]Shanthi, Sinchana, Soujanya G Pai, Nethravathi “REVIEW ON GREEN CLOUD COMPUTING”/ International Research Journal of Modernization in Engineering Technology and Science e-ISSN: 2582-5208

[39] Mr. Nayan Agrawal, Ms. Jasneet Kaur Saini "Review on Green Cloud Computing: A Step Towards Saving Global Environment"/ International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181

[40]Dr. Ashish Khanna, Dr. Piyush Kumar Pareek "Shifting from Cloud Computing to Green Cloud and Edge Computing"/ Electronic copy available at :https://ssrn.com/abstract=438778