

## A STUDY ON ADOPTION OF CARBON-NEUTRAL ENERGY BY ENTERPRISES IN PROMOTING GREEN CLOUD COMPUTING: ADVANCING TOWARDS ENVIRONMENTAL SUSTAINABILITY

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**Abstract** - In recent years, the field of Information Technology has experienced significant progress. The emergence of cloud computing has revolutionized the accessibility of information. Cloud computing has become a pervasive technology, finding applications across enterprises of all sizes and industries. However, the expansion of cloud infrastructure has led to a notable rise in energy consumption and carbon emissions. Operational expenses are on the rise, with energy-intensive data centres consuming a considerable portion of enterprise budgets. To address these challenges, Green cloud computing has emerged as an effective and energy-efficient solution. This paper explores various renewable energy sources for powering data centres and provides an overview of green cloud initiatives implemented by enterprises worldwide. Additionally, this paper provides a comprehensive overview of the initiatives undertaken by enterprises globally to embrace green cloud computing practices and reduce their carbon footprint.

**Index Terms:** Operational expenses, Renewable energy, Cloud –Infrastructure, Energy intensive, carbon emissions.

### I INTRODUCTION

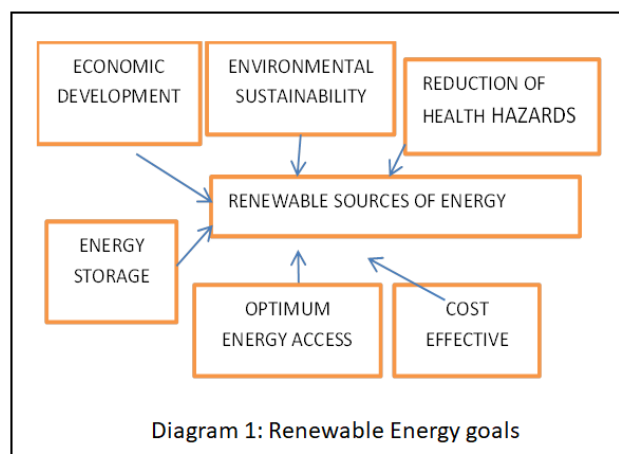
Over the past few decades, there has been a substantial rise in the utilization of high-speed networks and the handling of millions of concurrent transactions in e-commerce. Enterprises and businesses are increasingly recognizing the significance of Cloud Computing in establishing their operations. However, as the cloud computing industry expands and energy consumption, along with carbon emissions, increases, it becomes crucial to manage the sector's energy usage and emissions in an environmentally sustainable manner to ensure continued long-term growth. With businesses transitioning from on-premises data centres to cloud computing solutions, adopting green technology represents a substantial opportunity to mitigate carbon emissions, benefiting both their operations and the environment.

Massive data centres handle the continuously increasing demand, managing hundreds or thousands of servers, cooling systems, and storage units. Leading companies such as Google, Amazon, Microsoft, eBay, and Yahoo operate extensive data centres worldwide. With computing advancements progressing rapidly, energy management remains a critical concern for the foreseeable future. The successful management of energy consumption in large-scale data centres requires a holistic approach that considers both the short-term operational needs of the business and the long-term sustainability goals.

As energy prices continue to rise and concerns about resource scarcity grow, businesses are recognizing the importance of energy efficiency across all stages, from planning to production and operation, it becomes essential for sustainable business practices. The effective approach to addressing the rising energy demand is the adoption of renewable energy sources, which offers a sustainable solution for meeting energy demands while reducing carbon emissions. Data centres, in particular, are embracing renewable energy as part of their energy portfolios. Recent studies indicate a growing trend among

companies to power their data centres using renewable sources like wind or solar energy, rather than relying solely on conventional energy sources such as thermal or coal. This shift not only helps companies reduce their environmental footprint but also demonstrates a commitment to sustainable business practices [1]. In the provision of energy for data centres, conventional fossil fuels come with several limitations such as low utilization rates, significant pollution, and finite reserves. Consequently, there is an immediate need to prioritize the advancement of green renewable energy sources. Data centres need to boost their utilization of renewable energy by producing it on-site and adjusting their operations according to the available renewable energy sources, as the choice of energy sources directly impacts the carbon footprint. Renewable energy sources such as sunlight and wind are abundant and cost-free. Once the infrastructure is set up, a continuous supply of power can be generated [2]. By 2030, it is anticipated that wind and solar energy would make up close to 60% of all electricity generated in Europe. The importance of efficient energy usage is key factor in cloud data centres. The power consumption of the data centres is very high due to the energy required for computing and cooling purposes. Hence, in order to attain sustainability, it is very crucial for the enterprises to make efficient utilization of different types of renewable energy sources towards the initiative of greener planet.

Google prioritizes investments in renewable energy by funding the construction of new plants and utilizing the energy generated. Companies strategically select specific locations to host data centres, ensuring they can accommodate a consistent level of computing power. Each data centre is equipped with an on-site green power facility, utilizing solar, wind, or a combination of both, to achieve a desired energy consumption percentage. Given the significant impact of data centre location, cloud service providers must make careful choices. With numerous potential locations for data centres, the selection process involves evaluating various factors, including land availability, electricity costs, cooling system infrastructure, and climatic conditions, all of which influence the production of renewable energy from solar and wind sources. The companies decision-making process behind selecting data centres locations is complex and multifaceted, with careful consideration given to a wide range of factors. By prioritizing renewable energy and making informed choices about site selection, companies can not only enhance the efficiency and reliability of their data centres but also contribute to the broader goal of achieving a greener and more sustainable future. The economic viability of renewable energy investments is a significant factor for companies. While upfront costs for renewable energy infrastructure may be higher than traditional energy sources, long-term savings and potential financial incentives, such as tax credits and renewable energy certificates, make renewable energy projects financially attractive.



Businesses worldwide are increasingly adopting sustainable practices in response to the growing awareness of the climate crisis and its impact. As renewable energy sources such as wind and solar become more economically viable compared to fossil fuels, addressing environmental concerns has become a commercial necessity. Moreover, investors are recognizing the long-term implications of unsustainable business practices, further driving the shift towards sustainability. The declining costs of renewable energy technologies have made them increasingly competitive, prompting businesses to reconsider their energy procurement strategies. This transition is fuelled not only by a desire to reduce carbon emissions but also by the potential for cost savings and long-term sustainability. The shift towards sustainability in business operations is driven by a combination of economic, regulatory, and societal factors. The technology sector, being a major consumer of energy, has significantly invested in enhancing energy efficiency and has increasingly embraced renewable energy. However, despite these efforts, many sustainability plans for data centres still place a heavy emphasis on obtaining renewable energy certifications (RECs). The renewable energy adoption, along with other sustainability initiatives, will play a crucial role in helping businesses mitigate their environmental impact and build a more resilient and sustainable future.

## 2 LITERATURE SURVEY

In this study, the necessity of green cloud computing is thoroughly examined and analysed. The primary focus of this work is on highlighting the importance of green cloud computing in environmental sustainability. It includes investigation of green computing practices, carbon footprint measurement, exploration of future prospects, and identification of challenges faced by conventional energy sources in the present scenario.

[3] Sindhu focused on those policies that can reduce data centres energy costs, resulting in a highly competitive cloud industry. End users can also benefit from lower energy bills

[4] Monali Jumde reviewed various approaches applied by researchers to make energy efficient cloud computing. The review has offered an assessment of the literature on green and energy-efficient cloud computing and explored the idea of cloud computing to design a green cloud.

[5] Rajkumar Buyya has discovered a number of untapped resources that can aid in maximising Clouds overall energy effectiveness. An analysis of the shortcomings of earlier solutions is done and put all together out a Green Cloud Framework which provided some evidence to support it.

[6] A.Sivasankari explains how computers are now a need for everyone. Without computers, production, The production of green energy from renewable resources like sun and wind is very location-dependent. Location also affects the cost of land, power, and the installation of a cooling system. In order to provide a given constant amount of compute power, we want to effectively choose a set of sites and provision datacentres at these locations. Each datacentres will have a green power plant on-site (either solar, wind, or both), allowing the combined energy utilized by the datacentres to originate from green sources to a targeted extent

[7] Viney Goyal examines sustainable cloud technology and how it is evolving, reviews pertinent literature, and addresses consolidated green cloud architecture. The emphasis is on green cloud concepts, ideas, and methodologies as well as the research directions and challenges that must be overcome to run a large-scale environmental cloud computing infrastructure. Such a comprehensive green cloud research study will aid novice green study partners in understanding green cloud trends and spotting upcoming employment challenges in the region

[8] D. Chandrika offers an energy-alert layer for software architecture that would be in charge of examining the micro- and macro-metrics of data centre energy use before directing services to hosts that used less energy.

[9] Dr. Kumar emphasises environmental considerations, focusing on the need for green computing generally with regard to how and when electronic devices are disposed of, creating e-waste and pollution, as well as the areas where green computing is highly desired in terms of cost and energy savings, as well as initiatives by governments and corporate sectors in this direction.

This study emphasizes the transformative potential of green cloud computing in promoting environmental sustainability, driving economic growth, and fostering innovation. By embracing sustainable practices and overcoming existing challenges, organizations can position themselves as leaders in the transition towards a greener and more resilient future.

### **3 SELECTION OF SITES**

The production of green energy from renewable sources like solar and wind is intricately linked to specific geographic locations. The availability of sunlight and wind patterns varies significantly depending on factors such as latitude, topography, and weather conditions. Consequently, the feasibility and efficiency of generating renewable energy at a particular location are heavily influenced by these geographical factors [ 10]. The location of renewable energy production facilities also impacts various other aspects of their operation. The cost of land can vary significantly depending on the region, with factors such as proximity to urban centres, land availability, and land use regulations affecting land prices. Similarly, the availability and cost of power infrastructure, including transmission lines and substations, can vary depending on the location, further influencing the overall cost of renewable energy production.

Additionally, the installation and operation of cooling systems in renewable energy facilities are also influenced by their location. In regions with higher temperatures, such as desert areas, cooling systems may need to work harder to maintain optimal operating temperatures, potentially increasing energy consumption and operational costs. Conversely, in cooler climates, less energy may be required for cooling, leading to potential cost savings. In the context of data centres, which are significant consumers of energy, the selection of locations for establishing these facilities is crucial for ensuring operational efficiency and sustainability. To provide a consistent amount of computing power, it is essential to strategically choose a set of sites for data centres provisioning. This involves evaluating various factors such as access to renewable energy sources, proximity to major population centres, and availability of skilled labour. The data centres are increasingly integrating on-site green power plants to align with sustainability objectives and reduce carbon emissions. These facilities utilize renewable energy sources like solar and wind to power data centres operations, reducing dependence on conventional energy sources and minimizing environmental impact. By generating renewable energy on-site, data centres can achieve targeted levels of energy consumption sourced from green sources, contributing to broader sustainability initiatives.

### **4 SUSTAINABILITY AND RENEWABLE SOURCES OF ENERGY**

The persistent reliance on fossil fuel-based energy sources like coal, oil, and gas has become increasingly problematic due to the escalating global energy demand and population growth. This reliance has led to various issues, including the depletion of fossil fuel reserves, greenhouse gas emissions, environmental degradation, geopolitical tensions, and volatile fuel prices. In contrast, renewable energy sources offer a sustainable alternative as they are derived from ongoing energy flows in our environment. To ensure that renewable

energy is genuinely sustainable, it must exhibit specific qualities. Firstly, it needs to be unlimited, indicating that it is not bound by finite resources and can be consistently renewed through natural mechanisms.

Despite the considerable benefits of renewable energy sources, they come with certain drawbacks. One such limitation is the variability in power generation due to seasonal changes, as many renewable sources rely on specific climatic conditions. Consequently, their utilization necessitates sophisticated design, planning, and optimization methods to ensure consistent output. The renewable technologies are hailed as clean energy sources, and their optimal utilization can lessen environmental impact, minimize secondary waste generation, and contribute to sustainability in line with economic and social needs. These energy sources originate from natural and continuous energy flows in our immediate environment. By displacing conventional energy sources reliant on fossil fuels, renewable energy technologies offer a promising avenue for reducing greenhouse gas emissions and addressing global warming. The renewable energy sources are more evenly distributed across the globe compared to fossil fuels and are typically less subject to market trading. This characteristic enhances accessibility and opens up possibilities for decentralized energy production.

**5 RENEWABLE ENERGY MANAGEMENT OPTIONS**

As energy demand continues to escalate in the era of cloud computing, concerns the non-renewable energy resources are depleting. Data centres, which host numerous computers and consume vast amounts of power, are at the forefront of this energy demand surge. However, the inefficiency in energy usage poses a significant hurdle, particularly for large businesses, limiting their growth potential. Therefore, there is a notable shift towards prioritizing renewable energy efficiency within data centres as a response to this challenge[11].

Although there has been notable progress in transitioning to clean electricity, the proportion of power generated from renewable sources remains relatively small. This is particularly concerning given the increasing demand for electricity, especially in data centres. Currently, a significant portion of electricity is still generated using high-carbon-intensity fuels such as coal and natural gas, posing environmental challenges. The increasing demand for electricity, particularly in data centres, underscores the urgency of accelerating this transition. By embracing renewable energy sources and overcoming the associated challenges, collectively businesses can pave the way for a greener planet.

Cloud data centres	Carbon Emissions metric tons	Renewable Usage Deadline	Fossil Fuel Usage deadline	Electricity consumed
Google	38964	2017	Still using	12.4 terawatt-hours
Apple	55,200	2012	Still using	2.58 terawatt hours
Microsoft	123,704	2025	Still using	4.9 terawatt hours
Amazon	9,62,0000	2030	Still using	200 terawatt hour
Facebook	55,000	2020	Still using	7 terawatt hours

**Table 1 Comparative Of Substantial Renewable Cloud Datacentres**

Within the data centres industry, Google and Microsoft are widely recognized as the foremost leaders in adopting renewable energy. Furthermore, by incorporating more wind turbines, a data centres can strengthen its position in real-time market and reserve bids. capitalizing on its locally generated power.

## 6 COST EFFECTIVENESS

The use of green computing is incredibly economical. It's interesting to note that "Wind" is far less expensive than "Solar". This is due to the fact that constructing a wind farm costs less money per kW than constructing a solar farm. When there is no storage and we desire a high proportion of green energy that is the only situation in which solar is more cost-effective than wind. Solar energy is more reliable and predictable since it is less variable. [8]"The total energy from solar radiation falling on the globe was more than 7,500 times the World's total yearly primary energy consumption of 450 EJ," the World Energy Council (2013) states (Urban & Mitchell, 2011). Among the renewable energy sources, wind has emerged as a significant source of the world's energy. The total energy from solar radiation falling on the globe was more than 7,500 times the World's total yearly primary energy consumption of 450 EJ," the World Energy Council (2013) states (Urban & Mitchell, 2011).

Among the renewable energy sources, wind has emerged as a significant source of the world's energy. There is wind everywhere, and some regions have a lot of energy density. As far as cost is concerned both solar energy and wind energy are the best option for powering up data centres other than any other sources of renewable sources energy depending on location of data centres as well as climatic conditions By calculating the lowest cost for achieving various levels of renewable energy, it is possible to visualise the location selection[12] Due to the prevalence of fossil fuel-based power generation (coal, oil, and gas) and the exponential rise in world population over the past few decades, there is a rising demand for energy, which has resulted in problems of cost and environment[13]. In order to protect the environment and cost savings businesses who provide cloud services should use renewable energy sources instead of non-renewable ones as much as possible.

## 7 CONCLUSION

Energy plays a vital role in our daily lives, facilitating human development, economic growth, and productivity. Transitioning to renewable energy sources presents an opportunity to combat climate change and ensure a sustainable future that can meet the energy needs of future generations. However, this transition must be sustainable to effectively address environmental challenges. The objective of this paper was to assess the sustainability of renewable energy sources and explore the benefits of shifting from fossil fuel-based energy to renewable alternatives such as wind and solar energy. A qualitative study was conducted through a comprehensive review of relevant literature. The research highlighted various opportunities associated with renewable energy sources and emphasized the importance of adopting more energy-efficient practices. The efforts aimed at increasing the utilization of renewable energy and implementing clean fossil fuel technologies can play a crucial role in promoting environmental sustainability. Companies are increasingly focusing on the sustainability of renewable energy to ensure that technological advancements do not have adverse effects on the environment. The transition of companies from traditional, carbon-intensive energy sources to renewable alternatives can help mitigate the emissions of greenhouse gases, particularly carbon dioxide (CO<sub>2</sub>), thereby slowing down the rate of ozone depletion and contributing to the creation of a greener planet.

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