Green Cloud Computing: Sustainability, Applications And Challenges

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ABSTRACT

A viable paradigm for addressing the environmental issues raised by the cloud computing industry's explosive growth is green cloud computing. This paper offers a summary of the fundamental ideas and methods of green cloud computing, with the goal of lowering carbon emissions and fostering sustainability in data center operations. It looks at a number of tactics, such as designing with energy efficiency in mind, using renewable energy sources, allocating resources optimally, and managing hardware lifecycles successfully. Green cloud computing uses these strategies to reduce energy use, reduce carbon emissions, and encourage environmental responsibility without sacrificing the scalability, performance, or dependability of cloud services. Green cloud computing adoption provides financial incentives through lower operating costs and improved corporate social responsibility, in addition to environmental benefits.

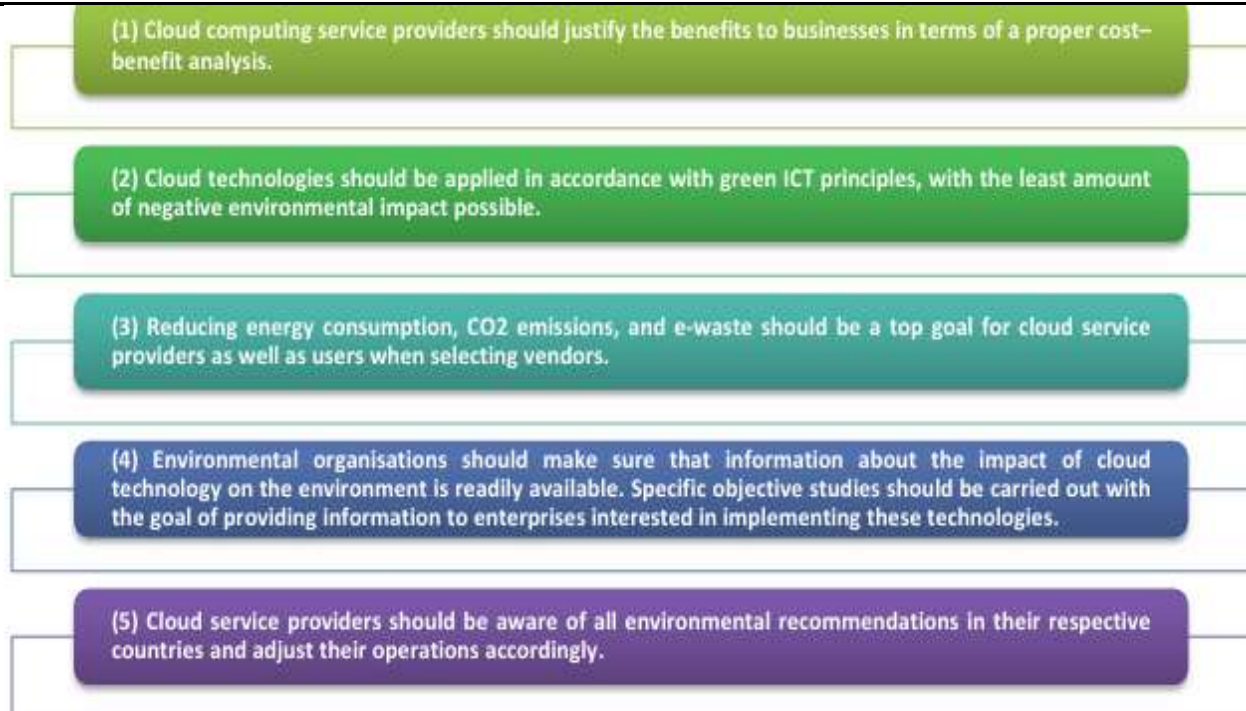**KEYWORD: Green Cloud Computing, Sustainability, Environment fortification.**

1. INTRODUCTION:

Customers around the world can access processing power and resources through cloud computing. It delivers excellent performance and cost savings compared to high-performance dedicated computing devices. However, this service requires huge data centers, consumes a lot of energy, and generates a lot of CO_2.[2] Green cloud computing was created to solve this problem by using renewable energy to reduce energy consumption and CO_2 emissions. The driving force behind choosing Green Cloud is a commitment to developing environmentally friendly, resource-efficient, low-carbon and recyclable solutions. Green computing research focuses on creating efficient clouds with environmentally friendly features, including power management, virtualization, high-performance computing, load balancing, central ecology data, reuse and recycling. Providing quality service to end users while realizing green computing for IT systems, achieving energy efficient control, and meeting performance guarantees have all become top concerns for vendors. cloud provisioning [2]. Figure-1 This diagram explain the relationship between cloud computing and green computing [12]
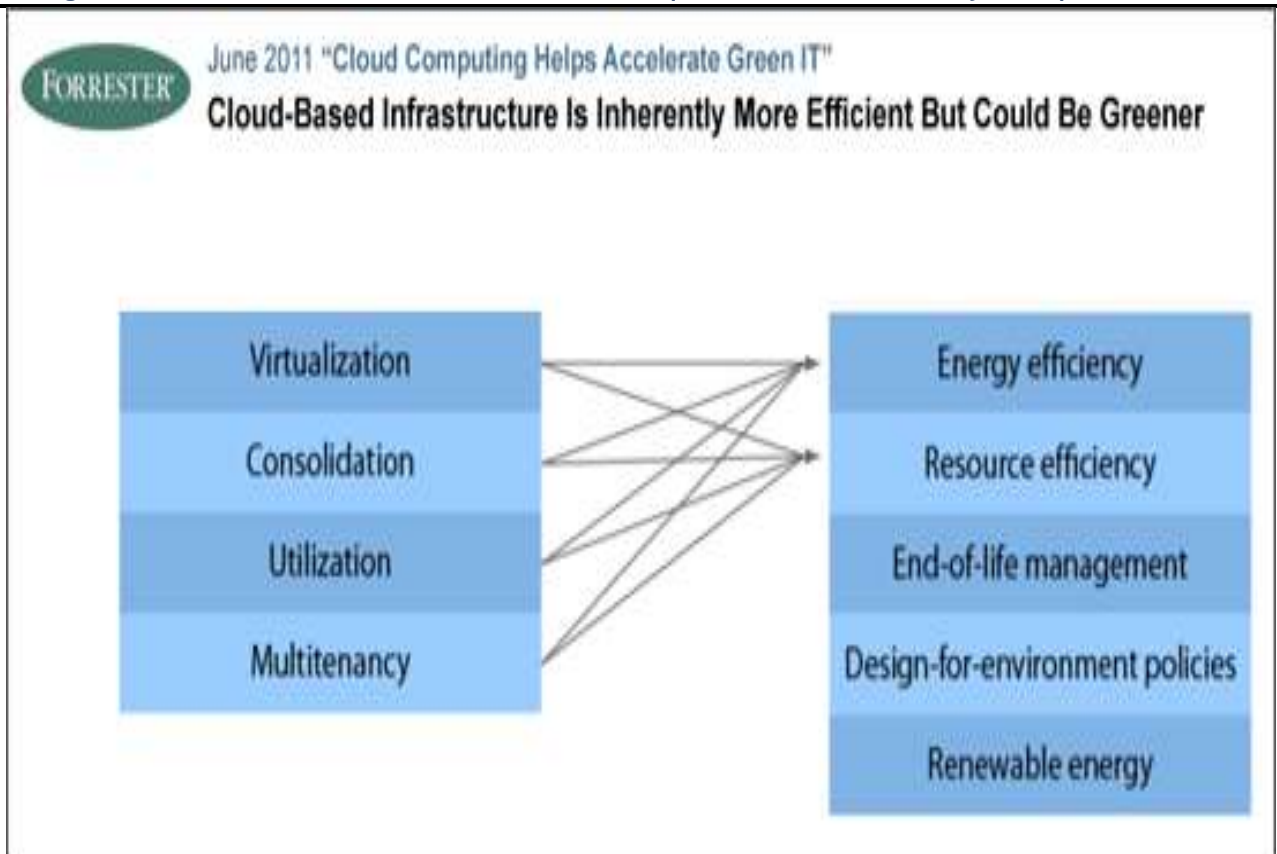
[12]Fig-1:Cloud based infrastructure is inherently more efficient but cloud be greener

The cloud computing service model involves the service provider providing a large amount of high-performance computing resources and high-capacity storage devices, which are then shared among end users as needed. While there are many different cloud service models, in general, end users subscribe to a service whose data is stored by the service, and their computing resources are made available on demand from a pool. End-user software applications may be included in the service provider's product. The cloud service model requires a high-speed network to connect end users to the service provider's infrastructure to be successful. There are many definitions of cloud computing, and the IT industry continues to debate future offerings. Green cloud computing (GCC) involves using computers and related resources in an environmentally friendly manner. Examples of such methods are energy-efficient central processing units, servers and peripherals, as well as reducing resource costs and properly disposing of e-waste. Green computing is "the science and practice of developing, industrializing, using and processing computers, servers and related subsystems such as displays, printers, storage devices as well as networks and interface with little or no environmental impact." Green computing aims to reduce the use of toxic chemicals, maximize energy efficiency throughout a product's life cycle, and encourage the recyclability or biodegradability of obsolete products. and manufacturing waste, such as green chemistry. The main areas of research are making the use of computers as energy efficient as possible, as well as developing algorithms and systems for computer technology related to efficiency. Figure 2 presents the roles to achieve GCC [14].

(1) Cloud computing service providers should justify the benefits to businesses in terms of a proper cost–benefit analysis.

(2) Cloud technologies should be applied in accordance with green ICT principles, with the least amount of negative environmental impact possible.

(3) Reducing energy consumption, CO2 emissions, and e-waste should be a top goal for cloud service providers as well as users when selecting vendors.

(4) Environmental organisations should make sure that information about the impact of cloud technology on the environment is readily available. Specific objective studies should be carried out with the goal of providing information to enterprises interested in implementing these technologies.

(5) Cloud service providers should be aware of all environmental recommendations in their respective countries and adjust their operations accordingly.

[14]   Fig-2 Roles of GCC

Moving to the cloud has its own benefits, such as simplicity, efficiency, and better maintainability. These benefits are enough to convince you. The added benefit of having a "green" environment when it comes to your IT may be just the extra motivation you need to move to the next generation of computing and IT management. While planting a tree once a year is a great way to contribute to a sustainable planet, settling into an environment that benefits the Earth every day is simply not possible. What can be compared?[10] According to the International Energy Agency (IEA), global carbon dioxide emissions from fossil fuels and industry will be 36.8 gigatons (Gt) in 2022. This is a 0.9% increase in energy production compared to 2021 and is the highest emissions level on record. The IEA predicts global CO2 emissions will continue to rise in the coming years, reaching 42 Gt by 2030 if no additional measures are taken to reduce emissions. This will cause world temperatures to increase by 2.7 degrees Celsius by the end of the century, causing devastating consequences for the planet. Time is running out for businesses around the world, facing increasing pressure to reduce emissions. With increasing regulatory and investor pressure, they find themselves at a crossroads. The world demands action and it demands action now. Luckily, there is a solution and it's in the Cloud. Make way for Green Cloud Computing, a revolutionary solution that reduces carbon emissions and energy consumption associated with cloud operations and infrastructure. This involves implementing sustainable strategies, optimizing resource allocation and promoting environmentally friendly practices in enterprise data centers. [16] If we continue to burn fossil fuels like there is no tomorrow (literally), experts estimate that we will run out of this precious resource by 2060. The scale and energy needs of these huge facilities mean they rely heavily on fossil fuels, which is not good news for our environment. Cooling systems, ongoing server operations, and redundant infrastructure all contribute to this significant energy demand. The consequences are clear: huge amounts of greenhouse gases are released into the atmosphere, putting our future in danger. [17] Fig-3 shows the electricity consumption and greenhouse gas emissions of data centers compared to all other industries from 2015 to 2030. The chart below shows that data centers data could account for a significant portion of global electricity consumption and carbon emissions by 2030.
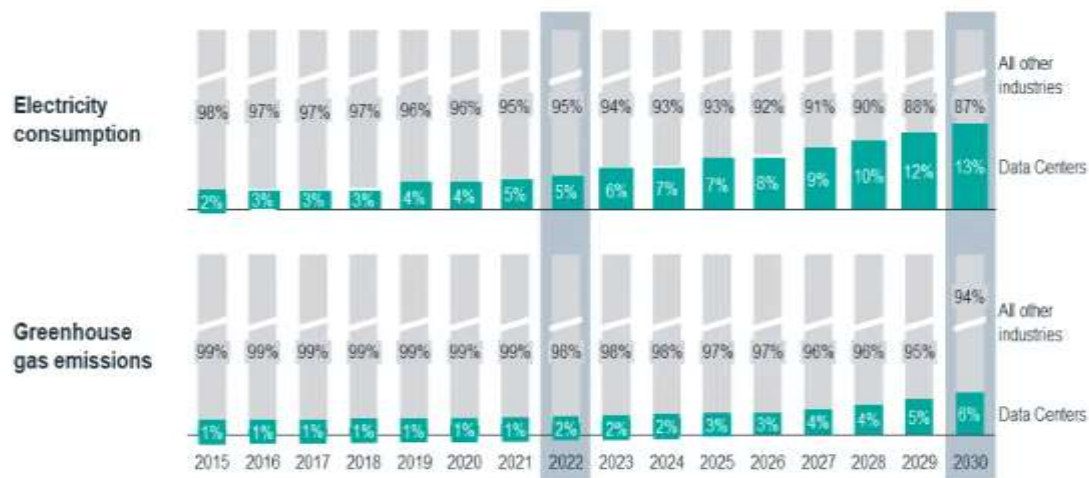
Fig-3 Data centres to adopt sustainable practices to mitigate their environmental impact

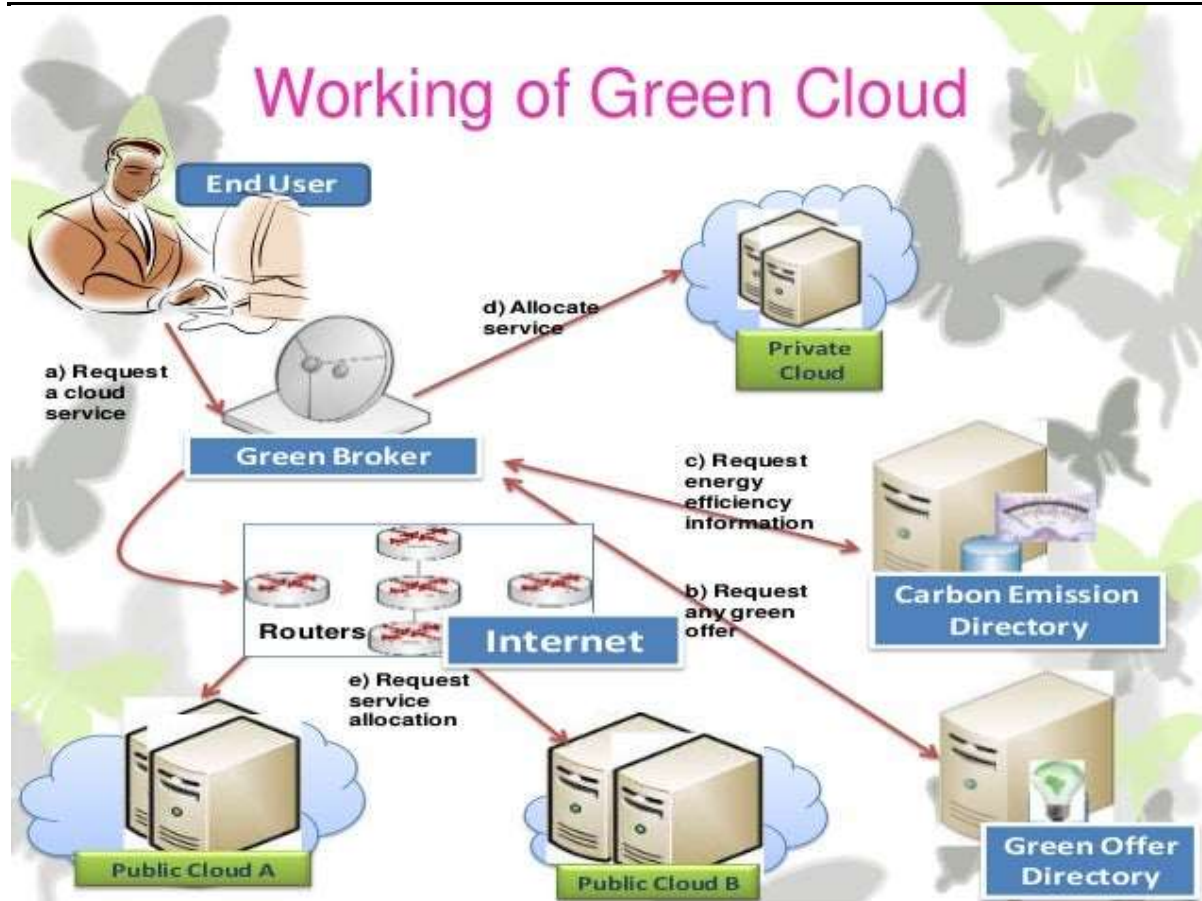## 1.2. Architecture of GCC:

GCC Architecture:

Here is Fig-4 explaining how Green Cloud works. It involves various constituents such as end users, green brokers, public and private clouds as well as directories of carbon footprint and green transactions. The process begins when an end user requests a cloud service, which is then managed by Green Broker to ensure energy-efficient resource allocation while accounting for carbon emissions. [22] Green cloud computing is a sustainable approach to cloud technology that aims to minimize environmental impact. This includes activities such as server virtualization, using renewable energy sources, and efficient energy distribution. This model reduces energy consumption and carbon emissions, contributing to a more sustainable digital world.

End users: start requesting cloud services.
Green broker: manages requests and advocates for energy savings.
Cloud services: Public and private clouds provide requested services.
Directory: Contains carbon footprint data and green services to guide brokers.

[21]Fig-4 Architecture of GCC

2. Impact of GCC on environment:

Green cloud computing is essentially an approach to designing, producing, implementing, and using cloud computing infrastructure and resources in an environmentally friendly way. Its primary goal is to reduce energy consumption, minimize carbon dioxide emissions, and mitigate other negative environmental impacts associated with IT infrastructure. Green cloud computing is a sustainable approach that aims to reduce the environmental impact of cloud computing.

Here are some key points regarding its impact on the environment:

A)Minimize Carbon Footprint:

Green computing is a crucial approach to minimize the carbon footprint associated with technology.[24] Migrating to the public cloud can significantly reduce CO2 emissions. Cloud migrations have the potential to cut 59 million tons of CO2 emissions per year, which is equivalent to taking 22 million cars off the road.[23] According to EU data centers accounted for 2.7 percent of electricity demand in 2018, and if electricity demand continues on its current trend, this is predicted to increase to 3.21 percent by 2030, according to a European Commission study on energy-efficient cloud computing technologies. Data centers are using a substantial amount of energy, and as more businesses migrate to the cloud and data center growth continues, this demand will increase even though the 2018 rate is higher than the global average.

B)Lower Power Consumption:

Green cloud computing focuses on reducing energy consumption and minimizing the carbon footprint associated with cloud services. Cloud data centers use sophisticated power management systems to optimize energy consumption. This includes adjusting power consumption in real time to meet workload needs. [25] According to the International Energy Agency (IEA) data centers represent approximately 1–1.5% of the total global electricity consumption. In 2021, the global electricity usage by data centers ranged between 220 to 320 Terawatt hours, accounting for roughly 0.9%–1.3% of the worldwide electricity

demand. Notably, this signifies a notable increase of 10%–60% in data center energy consumption compared to the levels recorded in 2015.

C)Reduces Greenhouse Gas Emissions :

Cloud computing reduces greenhouse gas (GHG) emissions produced by data centers. [26]A recent Accenture survey found that cloud computing has a significant impact on carbon emissions; Businesses can reduce carbon emissions per user by 30% to 90% by switching to cloud computing. Measuring and reducing carbon emissions is not an easy task for any business, but moving to a cloud-based IT ecosystem is a good start.

D)Dematerialization:

The opportunities and benefits offered by the cloud ecosystem include instant sharing of digital documents. or parts thereof, on any device, from anywhere. Dematerialization is defined as the replacement of high-carbon physical products with new virtual equivalents. By switching to a cloud-based IT system, your business will be less dependent on physical hardware and machinery, you will consume less energy and reduce your impact on the environment. In turn, environmental sustainability will lead to improved profits through increased efficiency, reduced costs and improved sales.

E)Data center location:

Choice Data center location strategy, taking into account factors such as access to renewable energy sources and climatic conditions favorable for natural cooling. and proximity to users to reduce latency contribute to the sustainability of cloud computing.

Green cloud computing aims to balance the growing demand for services cloud with environmental sustainability, reducing carbon emissions, energy consumption and other negative environmental effects associated with traditional data center operations.

3. GCC in Real life:

Green cloud computing refers to steps taken by service providers to improve the environmental profile of their data centers by implementing green computing methods. [27]The resulting green clouds can also contribute to broader environmental, social and governance (ESG) agendas at the cloud providers themselves and at the companies that use their services . Greener IT is a common element in companies' ESG initiatives, aiming to improve the environmental and social impact of organizations, while ensuring that their business operations are ethical and fairness.

In this section, we discuss the top companies based in GCC Countries. and provides green hosting services worldwide.

Google Cloud:

[28] Google has a long history of clean energy: in 2007, Google became the first major company to go net neutral carbon. And in 2017, Google became the first company our size to source 100% of its electricity with renewable energy. [29]Google Cloud's commitment to operate 24/7 on carbon-free energy by 2030. Google aims to shed its carbon legacy and become the first major cloud provider to run entirely on carbon-free energy.

Amazon Web Services (AWS):

[30] AWS focuses on efficiency efficiency and continuous innovation across our global infrastructure, as we continue our journey to power our operations with 100% renewable energy by 2025. AWS is committed to meeting Amazon's net-zero carbon emissions target by 2040.

Microsoft Azure:

[31]Azure has committed to reaching a carbon-negative target by 2030 , removing more carbon from the atmosphere than it emits . Microsoft invests $1 billion in the Climate Innovation Fund to accelerate the development of carbon reduction, capture and removal technologies.

IBM:

[32]This organization reduces greenhouse gas emissions . 65% by 2025 compared to the base year 2010. The most important thing in the fight against climate change is to actually reduce emissions. The company's net-zero emissions target also comes with a specific numerical target for the residual emissions that are likely to remain after IBM has done everything possible to reduce them in its operations. me. Provide 75% of the world's electricity from renewable sources by 2025 and 90% by 2030. Use viable technologies, such as carbon capture (in or before 2030), to remove emissions equal to or greater than IBM residue levels.

4. Benefits Of GCC:

Adopting green cloud computing practices benefits both organizations and the environment by promoting resource efficiency, reducing waste, and minimizing energy consumption.
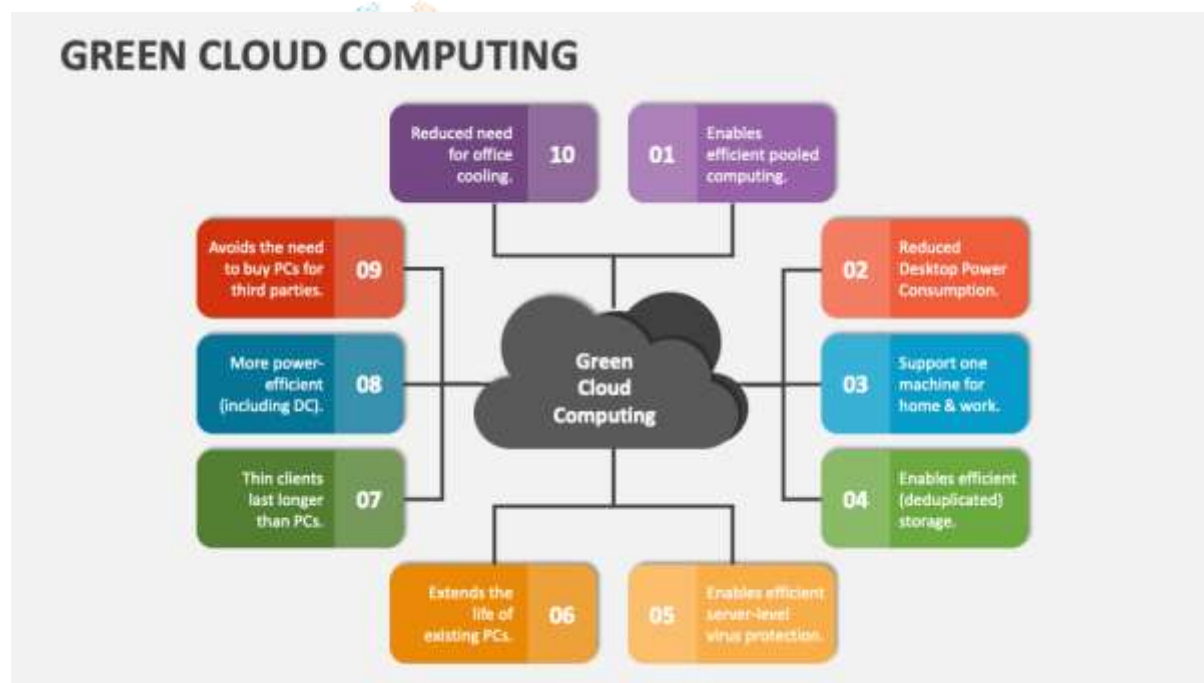
[11] Fig-5 Reason to adopt green cloud

Fig-5 provides a brief explanation of "Green Cloud Computing" and highlights 10 specific benefits of adopting environmentally friendly practices in cloud computing.

1. Enables efficient multi-tenant computing:
By using shared resources efficiently, green cloud computing enables better utilization of computing power. This can help save costs and reduce energy consumption.

2. Reduced desktop power consumption:
Green cloud computing prioritizes thin clients and virtual desktops, which consume less power than traditional desktops. This reduction in energy consumption contributes to a more sustainable environment.

3. One-machine support for home and work:
With green cloud computing, users can access their work environment from home or any other location using a single device. This reduces the need to use multiple machines and minimizes energy consumption.

4. Enables efficient storage (deduplication):

Deduplication techniques in cloud storage help eliminate redundant data, leading to efficient use of storage resources. This not only saves space but also reduces the energy needs to maintain the storage infrastructure.

5. Enables effective antivirus protection at the server level:

Centralized security measures in green cloud computing improve antivirus protection. By securing servers at the data center level, organizations can reduce the energy spent securing individual devices.

6. Extend the life of existing PCs:

Instead of replacing old PCs, green cloud computing allows organizations to extend their lifespan. By accessing applications and data remotely, users can continue to use their existing devices, reducing e-waste.

7. Thin clients last longer than PCs:

Thin clients (thin devices that rely on cloud resources) have a longer lifespan than traditional PCs. This longevity contributes to sustainability by reducing e-waste.

8. More energy efficient (including DC):

Data centers play an important role in cloud computing. Green data centers prioritize energy savings through advanced cooling systems, efficient hardware, and renewable energy sources.

9. Avoid the need to purchase PCs to third parties:

Organizations can provide access to cloud-based applications without distributing physical PCs to third parties (such as contractors or temporary employees). time). This approach minimizes hardware purchases and associated energy consumption.

10. Reduce office cooling needs:

By centralizing computing resources in data centers, organizations can reduce heat generated in office spaces. This in turn reduces the need for air conditioning and cooling systems.

5. Challenges:

Implementing green IT on a large scale is not easy at all, as some influencers claim, because every strategy described as a means of implementation comes with some challenges. Some of these implementation challenges are discussed below:

Maintaining privacy:

Cloud computing is one of the "green" paths as it makes computing infrastructure and processing more efficient. fruit. Moving data to the cloud increases data vulnerability as the cloud service provider increases control over the data. Addressing privacy concerns in Green Computing is considered the biggest challenge because in general, Green Computing devices incorporate data sharing mechanisms with relevant organizations. users worry whether these devices will be more effective or at least as effective as before [33]. Concerns about compromise on efficiency were also seen as a challenge since computers must have the same characteristics such as efficiency, speed, flexibility, diligence, and other specifications, as well as ecological computing tools. Although these concerns turned out to be false as these "green" IT products will increase their lifespan[34].

Green design:

In green computing, the term green design gains importance is huge because it enables green IT to operate effectively. The term green design is used to produce products that use less energy. Therefore, considering the environmental conditions that have been severely disrupted by technology, Green Computing's production of environmentally friendly technological devices is a driving force due to many conflicting key goals that require speed. High operating efficiency and profitability. 35].

Cost:

To apply green IT at such scale, cost is the biggest challenge. Devices designed to make computing greener come at huge costs. In addition to terminal devices, servers that can serve green computing purposes will also require high costs. Giants can manufacture and maintain such equipment, but it is nearly impossible for SMEs to budget for such expensive infrastructure.

6. Coclusion:

Cloud computing can be a new approach that combines existing innovations to improve asset utilization efficiency. The results of making these advances are mixed. Providers of these services as well as research experts commissioned by nature organizations have highlighted both positive and negative factors about the impact of cloud computing on the environment. Green cloud computing represents a shift in worldview towards environmentally friendly computing technologies. By combining mechanical progress and natural management, it offers a compelling solution to the twin challenges of advanced development and climate change, paving the way for an advanced biological system Stronger and easier to maintain. Choosing green cloud computing offers far-reaching implications for global support operations. By controlling energy use, reducing nursery emissions and promoting the use of renewable energy, it contributes to global goals to combat climate change and nurture a viable future. more competitive for the coming ages. Green cloud computing highlights its important role in regulating natural impacts while sustaining the exponential growth of computerized platforms.

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