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Green Cloud Computing (GCC), Applications, Challenges and Future Research Directions

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Abstract

Cloud computing is a rapidly evolving field of communication and information technology, posing new environmental issues. Because cloud computing technologies are scalable, stable, and trustworthy, and provide great performance at a cheap cost, they have a wide range of application fields. The cloud computing revolution is reshaping modern networking and presenting both economic and technological benefits, as well as potential environmental protection prospects. These technologies have the potential to boost energy efficiency while also lowering carbon emissions and e-waste. These characteristics have the potential to turn cloud computing into green cloud computing. The main achievements of green cloud computing are reviewed in this survey. First, a brief introduction to cloud computing is provided. Following that, recent studies and advancements are discussed, with environmental issues being addressed especially. Finally, future research prospects for green cloud computing are discussed, as well as open issues.

Keywords: *Sustainable, Cloud Computing, Green Information, Environmental Protection.*

1. Introduction

The widespread use of cloud computing in all fields necessitates a shift to Green computing, which reduces power consumption and CO2 emissions while allowing energy and power to be reused and recycled economically and efficiently. Thousands of data centers make up the cloud, allowing it to meet client demand online and on time. These data centers range in size from a few hundred to thousands of square feet. Running these server farms, as well as cooling fans for processors, consoles, monitors, network peripherals, lighting, and cooling systems, necessitates a significant amount of power. In 2012, the total power consumption of these data centers was roughly 38 Giga Watt (GW) [1], which, if correctly employed, may have been enough to meet the energy needs of all residential households in the United Kingdom. This represents a 63 percent increase over the power use in 2011. GIt will be around 43 GW in 2013. New network-based services are becoming possible as high-speed Internet and corporate IP connections become more widely available [2]. While Internet-based mail services have existed for a long time, service options have lately extended to incorporate network-based storage and computing. These new services are available to both businesses and individuals [2-4].

The cloud computing service model entails the supply of huge pools of high-performance computing resources and high-capacity storage devices by a service provider, which are then shared among end users as needed [5-7]. Although there are many different cloud service models, in general, end users who subscribe to the service have their data hosted by the service and computing resources provided on demand from a pool. The end user's software applications may be included in the service provider's offering. The cloud service paradigm requires a high-speed network to connect the end user to the service provider's infrastructure in order to be successful. There are numerous definitions of cloud computing, and the IT industry continues to debate future services [8-10].

Green cloud computing (GCC) is the use of computers and related resources in an environmentally friendly manner. Energy-efficient central processing units, servers, and peripherals, as well as reduced resource spending and proper disposal of electronic waste, are examples of such methods. Green computing is "the science and practice of resourcefully and efficiently developing, industrializing, using, and disposing of computers, servers, and associated subsystems such as monitors, printers, storage devices, and networking and interface systems with low or no environmental impact." Green computing aims to decrease the use of hazardous chemicals, maximize energy efficiency during the product's lifetime, and encourage the recyclability or bidegradability of obsolete products and production waste, similar to green chemistry. Key areas of research include making computer use as energy-efficient as possible, as well as developing algorithms and systems for efficiency-related computer technology. Figure 1 briefs the roles to achieve GCC.

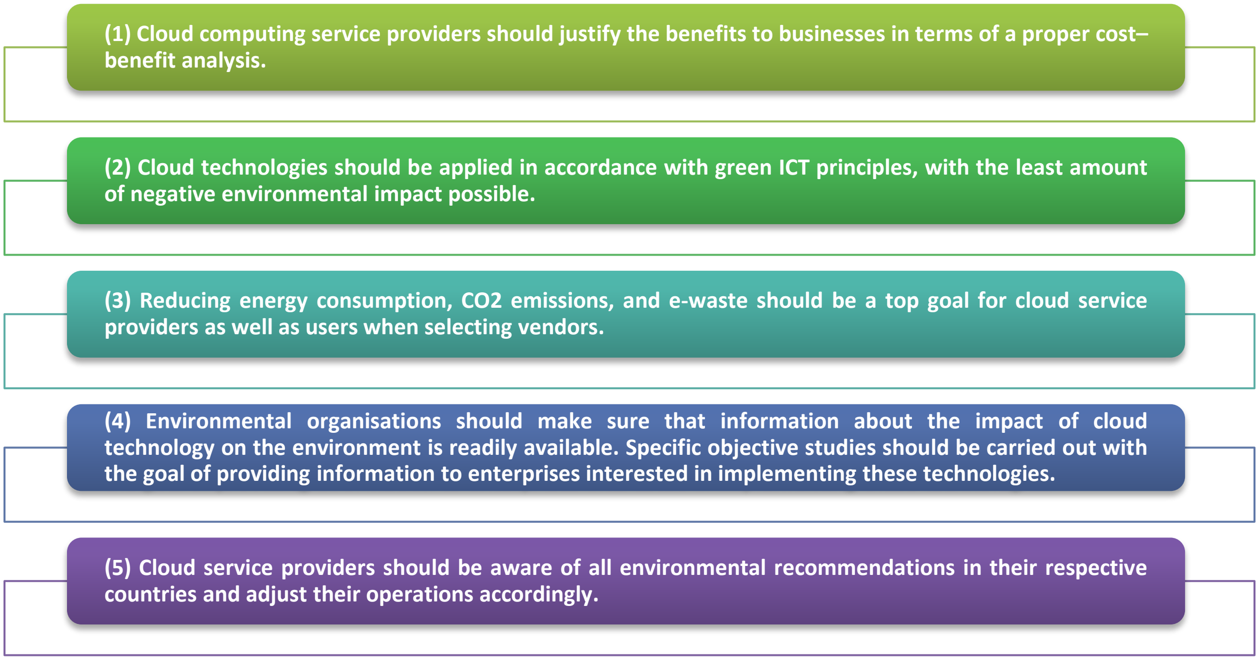

Fig.1. Roles to achieve GCC.

Moving to the cloud provides its own set of advantages, such as simplicity, efficiency, and better maintenance. Those advantages should be enough to persuade you. The added benefit of having a "green" environment when it comes to your IT could be just the extra push you need to upgrade to the next generation of computing and IT management. While planting trees once a year is an excellent method to contribute to a sustainable planet, relocating to an environment that gives back to the Earth every single day of operation is simply incomparable. Figure 2 briefs the reason behind making the Cloud green.

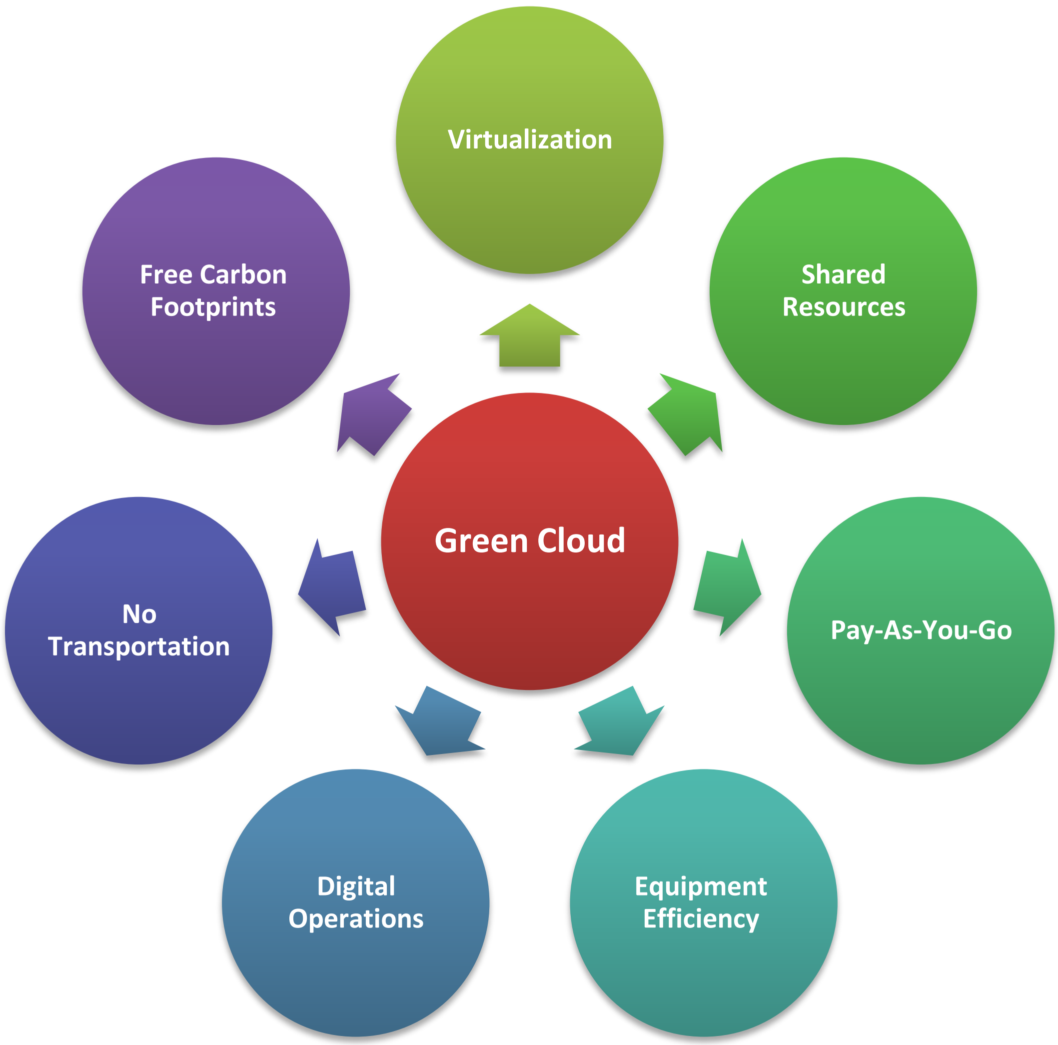

Fig.2. Reasons that Makes the Cloud Green.

Furthermore, the majority of energy sources are fossil fuels, which generate a massive amount of CO_2 each year from power plants. As a result, green computing is a cutting-edge technology that employs a power-awareness methodology. Figure 3 shows the green cloud architecture.

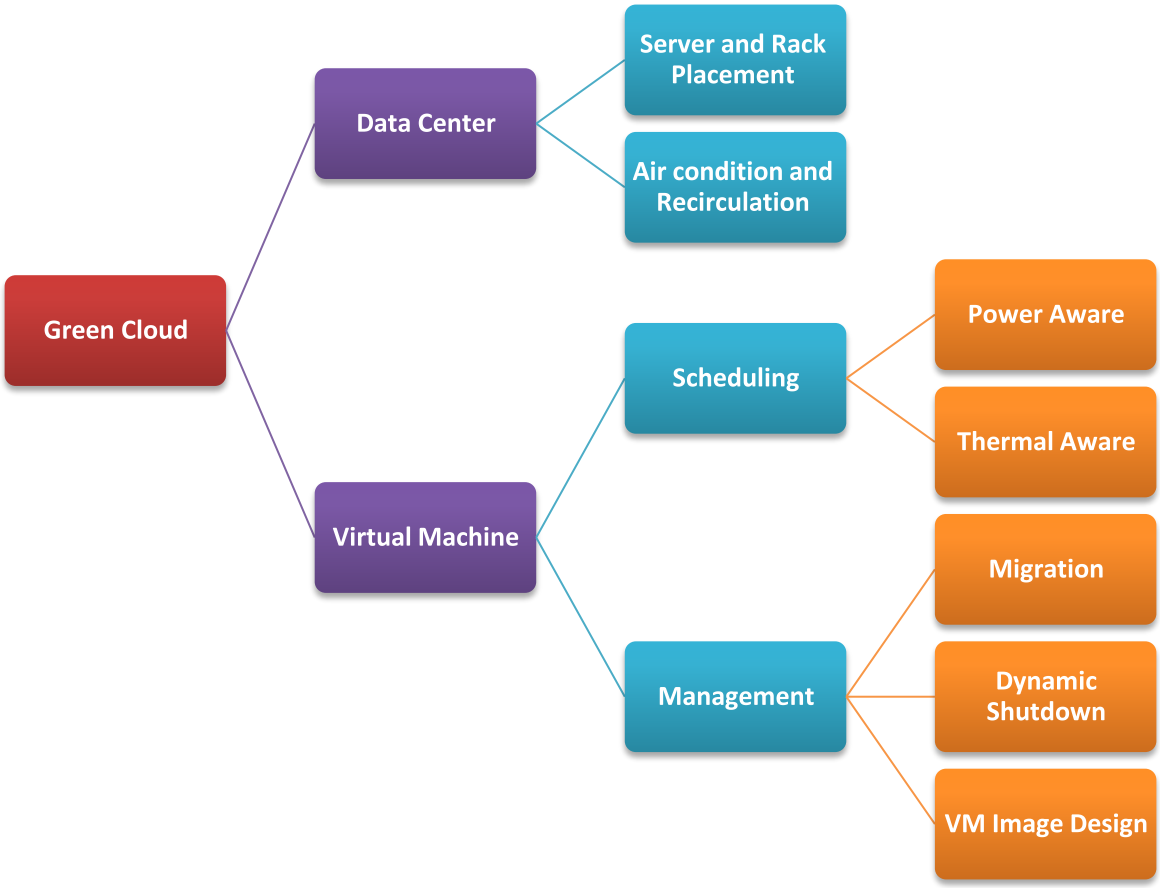

Fig.3. Architecture of the Green Cloud.

In this study, we provide an overview of cloud computing and its consumed energy and compare it to traditional energy consumption. In section 2, we presented a literature survey of most recent contributions for green cloud computing technology, as well as energy usage in switching and transmission, data processing, and data storage. Also, real life applications of GCC has been presented and discussed in section3 while section 4 spots the lights on challenges and future research direction in the field of GCC technology development. Finally, paper is concluded in section 5.

2. Literature Survey

We thoroughly verified various journals, conferences, white papers, and web sources as part of our study analysis on "Green Cloud Computing" to gather the most up-to-date information on green cloud computing and its characteristics as shown in Fig. 4. We give a literature review on green cloud computing in this section, along with pertinent previous research publications. Each noteworthy research activity in the field of green cloud computing is briefly discussed, along with author information. This data aids research academics in comprehending the evaluation of green cloud computing and the advancements made since its inception.

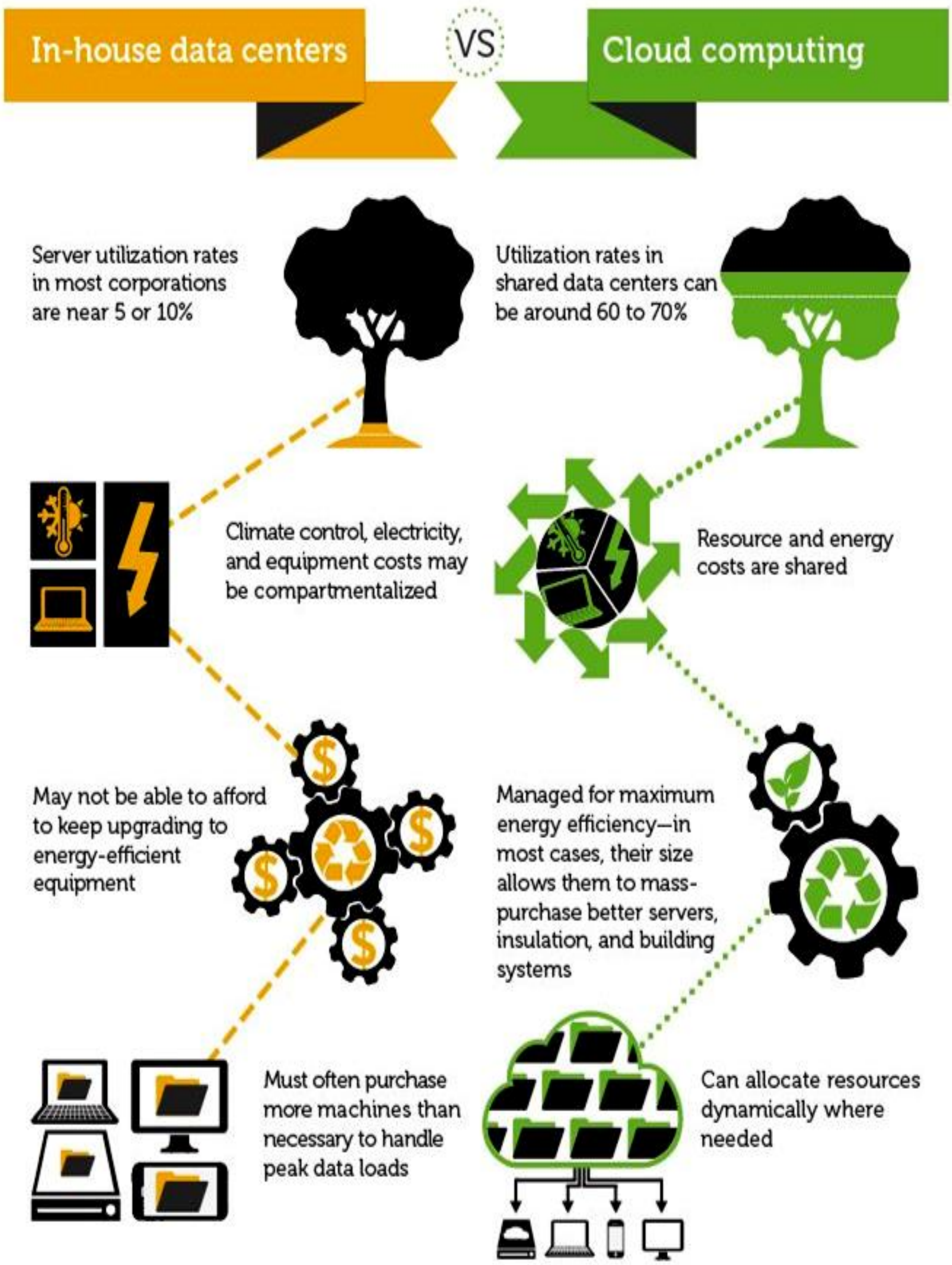

Fig.4. In-house Data Centers vs. Green Cloud Computing [11].

The resource allocation problem in clouds is addressed in this study using an energy-aware combinatorial auction-based model [12]. The proposed paradigm allows cloud users to submit virtual resource requests as bids using the given bidding language, which allows for the declaration of complementarities and substitutability among those resources. By solving an optimization problem, the model finds the most profitable mutually satisfiable set of winning bids, as well as the corresponding allocation of virtual resources to users, while taking into account the placement of virtual resources in relation to available physical resources in the cloud. The model additionally considers the non-linear energy requirements of physical resources based on their utilization levels during optimization to discover the lowest energy cost placement, resulting in an energy-aware solution to the resource allocation problem. Integer programming is used to formalize and formulate the associated optimization problem. Four heuristics were used to solve the intractable optimization problem. The findings show the advantages of the proposed model as well as the high-quality solutions offered by the recommended methodologies.

Further, to reduce EC and SLAV, a novel New Linear Regression (NLR) prediction model [13], host overload/underload, and VM placement strategy have been suggested. The fundamental goal of the NLR model is for it to pass through a straight line and a mean point. The proposed NLR model is used to forecast future CPU consumption. The proposed methods were evaluated using the CloudSim Simulator, which was extended. The results of the experiment reveal that the proposed algorithms lowered EC and SLAV in cloud data centres, and that they may be utilised to build a smart and sustainable environment for Smart Cities. On the basis of the peak energy consumption of data centres and the time span of work scheduling, a strong agile response task scheduling optimization algorithm is proposed in [14]. Techniques for agile response optimization are also used. The suggested technique may be used to examine the strong agile response optimization model, research the probability density function of the task request queue overflow, and request a timeout to avoid network congestion from the standpoint of task failure rate. The suggested algorithm may achieve task scheduling stability and efficiency, as well as efficiently improve the cloud computing system's throughput, according to experimental results.

In 2021, R. Gopi, et al. [15] offer an efficient way for reducing energy usage in mobile edge computing. In this context, the study paper offered a Green Cloud-based Queue Management system for 5G networks, which can help with latency and energy consumption issues. As a result of the suggested methodology, less energy is spent while servicing the users, resulting in lower latency. This problem can be considerably alleviated by relieving congestion and implementing the virtual list. The suggested model is compared to a conventional cloud model and a cloudlet based on throughput, latency, energy consumption, and normalised overhead as evaluation metrics, and the results are achieved by comparing the proposed model to a conventional cloud model and a cloudlet. The statistics suggest that energy use has increased significantly. The quality of the service improves as the throughput grows.

Moreover, in [16] an improved approach has been developed based on the ant colony optimization (ACO) algorithm, which may select the best virtual machine to migrate the cloudlet to in order to reduce execution time and energy consumption. With CloudSim, the efficiency of the suggested strategy was simulated in terms of execution time and energy consumption. This article includes an introduction that includes a full discussion of cloud computing as well as green cloud computing and related models. The virtual machine (VM) was also covered in greater depth in the introductory portion of this article, which allows cloud service providers to adequately oversee cloud resources without the need for human control. The paper then went on to explain the associated works and their discussions, as well as the innovative proposed load balancing based on the ACO technique, concluding that the proposed technique's execution time and energy usage are superior to the alternatives. The cloud is an endless resource pool that makes these resources available to various users. The amount of energy consumed in a cloud environment is determined by the number of factors that have constant or variable values. They corrected an energy consumption model in [17], and a power awareness scheduling approach was proposed. In addition, the study presents a model that depicts the relationship between workload, utility, power, and energy consumption. Various studies on energy optimization and power consumption have been conducted [18-21].

In order to make data centers more environmentally friendly and save energy, a new approach called Green Computing was developed. Moving toward optimal power consumption, as introduced in advanced green computing research, work is proposed as Powernap, i.e., an energy conservation technique in which servers are migrated between active and near-zero power idle states [22]. To save power more effectively, a new server state called "Somniloquy" is introduced [23]. Li et al. suggested a cost model based on total cost and utilization cost [24]. There was a drawback in the work because the calculation was dependent on a single hardware component. As a result, Jung et al. focused their research on physical host power consumption [25].

3. GCC in Real Life

On this section, we discuss the top enterprises that are GCC-based and offer green hosting around the world. In 26 countries, there are 342 green hosting firms are shown in Fig. 5 [26]. However, according to Buycpanel [27], Green Web Hosting is not only a good deed for the environment, but also one of the most practical ways to reduce carbon footprints. Other advantages include: Efficiency in Energy; Certification; Energy from renewable sources; Cost-saving; Shared Hosting E-waste minimization and Protocols. While looking for the best green hosts, we performed a lot of research. The Top leading companies in this field are as follows: A2 Hosting, SiteGround, InMotion DreamHost, iPage, HostPaPa, GreenGeeks and Fat Cow [28-29].

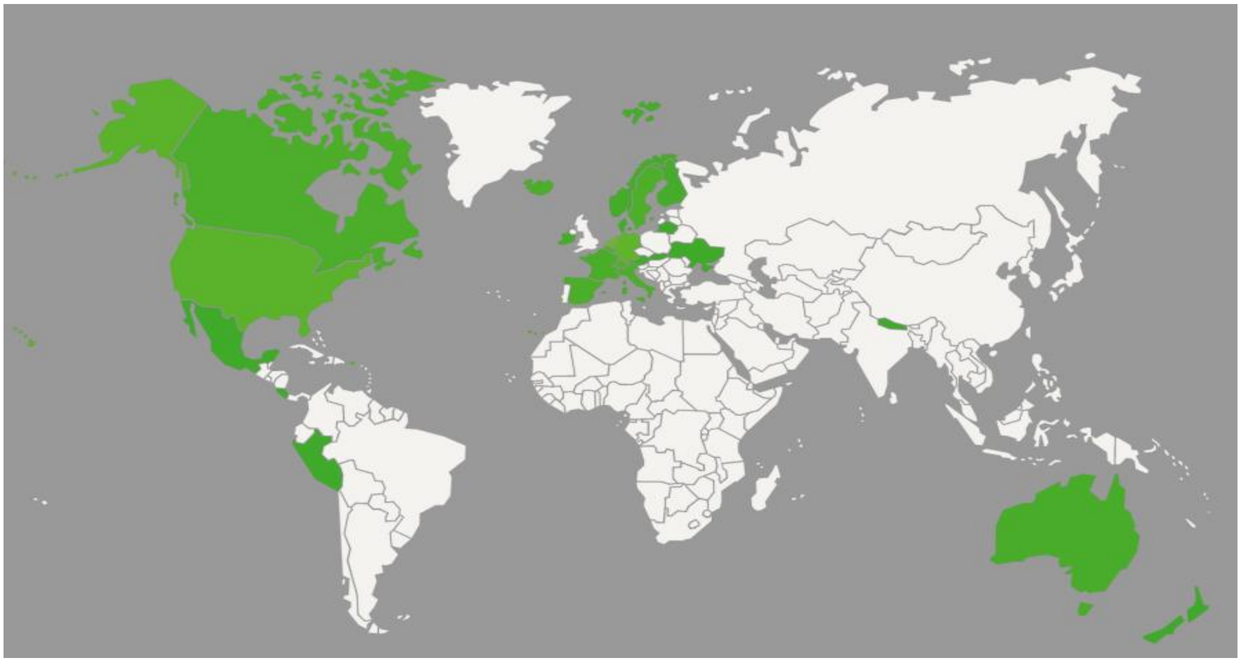

Fig.5. Green Hosting Companies Worldwide [26].

Due to Green Hosting Report [26], Netherland takes the lead in this field with 150 companies while Germany takes the second place with 49 companies. Both United Kingdom and United States come in the third place with 28 companies. Switzerland in the fourth place with 13 companies followed by Belgium with 10 companies in the fifth place.

Greengeeks [30], to replace the energy they consume, they buy wind energy credits. They buy three times as much renewable energy as their servers consume and return it to the grid. When you use GreenGeeks, your website becomes carbon neutral or negative. For every customer who signs up for their web hosting service, they also plant a tree. GreenGeeks does not necessitate any technical expertise. They have a one-click WordPress setup feature as well as a user-friendly onboarding process.

Kualo Green Hosting [31] comes in second. They are also an EPA Green Power Partner and run entirely on renewable energy. They've invested in energy-efficient servers and are transparent about their green business practices (they are a completely paperless company and their employees are encouraged to work remotely to avoid unnecessary travel and commuting).

DreamHost [32], to provide a green web hosting solution, they utilize a holistic approach. It has assessed and quantified their environmental effect, taking into account the energy required to power and cool their servers as well as the energy efficiency of their premises. They've even looked into the impact of their employees' commutes and made changes to their procedures as a result. According to DreamHost's website, their servers are "powered by grids that collect energy from renewable sources".

HostPaPa [33] was one of the first web hosting firms to pledge to turning green, according to their website. They buy green energy certificates to offset the electricity used by their servers and offices. Green credentials and banners are also available from Hostpapa, which you may display on your site to show that you are committed to turning green. Hostpapa is ranked fourth because, although being powered by green energy, it is significantly more expensive and offers fewer unlimited features. Furthermore, their green credentials and banners do not appear to be as polished and professional as GreenGeeks'. They provide value and are unique, but they don't appear to match GreenGeeks' high level of design and skill.

Fat Cow [34] was started in 1998 with the goal of delivering a straightforward, no-nonsense green web hosting solution. Fat Cow, like the other companies mentioned, buys renewable energy credits (wind energy) to offset their energy consumption. They also encourage their workers to embrace ecologically friendly work methods (e.g., responsible commuting and paperless offices). However, they merely give a high-level overview of these environmentally friendly activities and make no attempt to back up their statements with facts or detailed details. For example, Fat Cow does not specify how many credits they acquire to offset their energy consumption or where they purchase the credits. Other solutions on our list offer a lot more transparency and information. Fat Cow, on the other hand, is a seasoned and dependable web host that provides all of the typical features one would expect from a global company.

4. Challenges and Future Research Directions

Environmental protection research is a competition with winners and losers. All efforts are valuable and can lead to positive outcomes. The ultimate winner is society as a whole, as well as the future generation. In this field, green ICT is critical, and it is both a solution and a problem for the environment. This field includes green cloud computing as a significant component. A major portion of the study was devoted to cloud computing security [35] and service quality. This quality must encompass both consumer satisfaction [36] and environmental protection requirements. There are two categories of problems in designing a green cloud: technological and non-technical. Software design, virtualization approaches, and thermal-aware management strategies are some of the technical aspects of green cloud computing.

Green cloud computing relies heavily on software design. Applications can help with resource management and energy efficiency. It is necessary for software components to communicate effectively. The typology must be dynamic: resources should be added or withdrawn automatically dependent on server demand. The dynamic allocation of resources and energy, the reduction of job execution costs and time, and the decrease of energy consumption are some of the open problems. There are two challenges: international regulations are focused on cloud security issues, and international regulations differ from country to country. Some of them have enacted and implemented stringent environmental restrictions. Others are quite lax in this area, either because they don't have any regulations or because they don't apply them correctly. The expense of green cloud computing is another non-technical concern. These costs are passed on to cloud users, and cloud providers will raise their service prices as a result. Renewable energy usage is a non-technical issue. The intermittent nature of this energy is a barrier for cloud computing companies and throws off traditional methodologies for cloud operations planning. Some cloud providers have already constructed data centers in locations where renewable energy sources are available or will become available throughout the operational phase.

Green computing has been more popular in recent years, as the influence of greenhouse gas production on climate change and global warming has become clear. Aside from environmental concerns, economic needs are also a concern, since both IT electrical requirements and energy costs are on the rise. Future plans for green IT should incorporate efficient services and viable energy-saving solutions, because green computing will be built on efficiency rather than reduction in consumption in the future.

Although contemporary green computing research has addressed some concerns, there are still others that need to be investigated further. [37-39]. Green Cloud Computing is one of the green technology trends. The cloud computing effort makes data and services available to people all over the world.

The cloud computing effort makes data and services available to people all over the world. Different indicators identified by experts have been used to assess the cloud computing data center's efficiency. As a result, cloud computing has been identified as a cost-effective way to address environmental concerns [40-45]. Figure 6 briefs GCC future research directions.

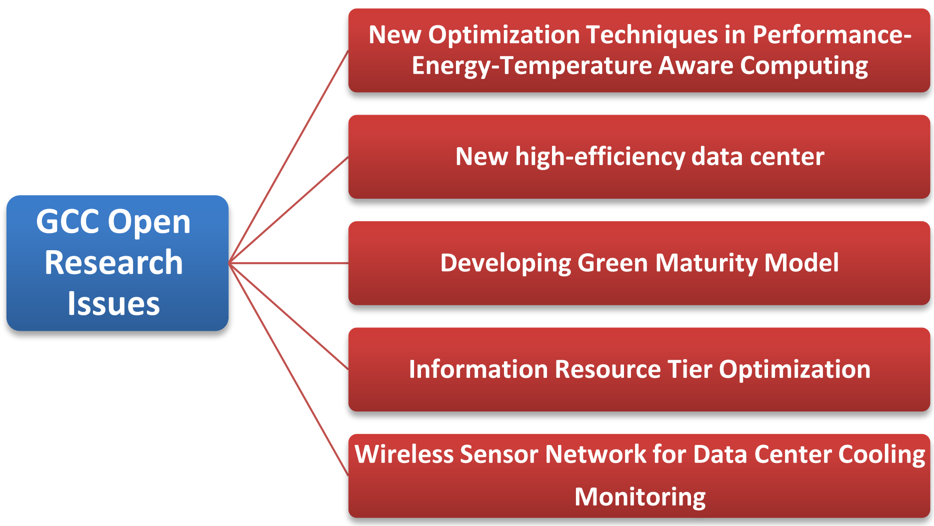

Fig.6. GCC Future Research Directions.

5. Conclusions

Cloud computing is a novel approach that combines existing technologies to improve resource use efficiency. The outcomes of implementing these technologies are diverse. Suppliers of such services, as well as writers of research commissioned by environmental organizations, have highlighted both positive and negative elements of cloud computing impact on the ecosystem. In general, cloud computing is likely to favor a harmonious relationship with the environment to the extent that ICT equipment manufacturers and companies providing cloud computing services align themselves with environmental policies and agree to non-governmental organizations' proposals for reducing the negative effects of hardware and software. Green cloud computing is the technology of the future that supports the environment, reuses consumed power and energy, and efficiently optimizes resources. Green computing aims to reduce CO2 emissions in the environment, making the IT industry more environmentally friendly. As we move toward cloud computing and use it in a variety of fields such as disaster recovery, service provisioning, online data storage, data retrieval from any location at any time, and so on, we must ensure that it is environmentally friendly; otherwise, the benefits of cloud computing will soon become disadvantages for the environment. The information gathered in this paper should assist readers understand the current state of green cloud computing. As a consequence of our research, we've identified the following factors that cloud providers and consumers should consider if cloud computing is to have a positive impact on the environment.

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