

Master's Thesis On

# **ROLE OF GREEN COMPUTING IN REDUCING ENVIRONMENTAL HAZARDS**

*FOR THE PARTIAL FULFILLMENT OF THE REQUIREMENT  
FOR THE AWARD OF  
MASTER OF BUSINESS ADMINISTRATION*

**UNDER THE GUIDANCE OF  
Prof. Sandeep Sharma**

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**14 May, 2022**

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## **Certificate**

This is to certify that the Master's Thesis " Role of green computing in reducing environmental hazards " has been prepared by Mr. Yatindra Narain Chaturvedi under my supervision and guidance. The project report is submitted towards the partial fulfillment of 2 year, Full time Master of Business Administration.

Name & Signature of Faculty

Date

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### **Declaration**

I, Yatindra Narain Chaturvedi, Roll No. 20GSOB2010294, student of School of Business, Galgotias University, Greater Noida, hereby declare that the Master's Thesis on " Role of green computing in reducing environmental hazards " is an original and authenticated work done by me.

I further declare that it has not been submitted elsewhere by any other person in any of the institutes for the award of any degree or diploma.

Name and Signature of the Student

Date

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## Abstract

If we think computers are non-polluting and consume very little energy, in fact the use of computer plays a big role in environment pollution. It is estimated that out of \$250 billion per year spent on powering computers worldwide only about 15% of that power is spent computing, the rest is wasted idling (i.e. consumed by computers which are not in use but still turned ON). That consumed energy is the main reason of CO<sub>2</sub> emission, thus, energy saved on computer hardware and computing will equate tonnes of carbon emissions saved per year.

Green computing benefits the environment. Reduced energy usage from green techniques translates into lower carbon dioxide emissions, stemming from a reduction in the fossil fuel used in power plants and transportation. Conserving resources means less energy is required to produce, use, and dispose of products.

In fact, the Internet risks becoming one of the most polluting sectors, but it is above all the production of electronic devices that aggravates the climate and ecological crisis, because of the toxic raw materials and the complex processes, requiring a lot of energy and a lot of water. It takes months to make a microchip, during which a long series of cuts and finishes generate considerable waste compared to the size of the finished product.

With current technologies, the production of a single computer involves the emission of 227-270 kilos of carbon dioxide. The consumption of water and the amount of waste from the electronics industry are also considerable: according to The Guardian, in the first three months of 2021 the Intel plant in Ocotillo had already produced 15 thousand tons of waste, of which 60% dangerous. and consumed more than 4 million litres of water and 561 thousand kilowatt-hours of electricity.

The situation is aggravated by the speed with which equipment becomes obsolete, the growing demand for electronic items, and the difficulty of disposing of components. Furthermore, the percentage of differentiated electronic waste is very low – around 14% in Europe – a sign that a large part of it ends up directly in landfills.

Using devices also entails an important overall consumption of electricity, especially if data is transferred online. Although the single user may consume little, the billions of connected items emit the same amount of CO<sub>2</sub> as a small country. This is why green cloud is essential in the fight against climate change.

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It is not only a problem of pollution but also of energy availability: if the energy demand continues to grow at this rate, there is a risk of not being able to satisfy it, not with renewable sources alone.

Gartner forecasts a rapid global expansion of cloud adoption, with end-user spending on cloud services projected to grow 21.7% in 2022. In addition, Gartner predicts that cloud spending will exceed 45% of all enterprise IT spending by 2026.

Companies have traditionally had two options for cloud migrations: easily accessible public clouds or customizable private cloud solutions. Today, hybrid cloud environments are expanding the possibilities for cloud infrastructure models, such as combining private cloud with public cloud or public cloud with an on-premises data center.

For example, data available to customers can be stored on a public cloud server while sensitive data is kept secure on private servers. Many organizations favor a hybrid cloud approach thanks to its flexibility, security, and cost-effectiveness.

Some industries have been resistant to cloud computing. In the financial services sector, for example, 70% of companies are still in the early stages of cloud adoption. Like finance, the healthcare industry is highly regulated and requires high levels of security to demonstrate compliance with Health Insurance Portability and Accountability Act (HIPAA) regulations.

For heavily regulated industries, industry clouds offer optimized servers, tools, and applications specific to industry needs. Industry-specific cloud solutions can help organizations accelerate their digital business transformation plans while meeting legal, regulatory, and operational requirements.

According to Forrester, companies will look for cloud service providers not based on the number of available services, but by which solution meets compliance parameters in their specific vertical.

Employees prefer remote work for many reasons, including money saved by not having to commute or spending money on items like coffee, lunch, and dry-cleaning expenses.

By shifting to full-time remote work, employees avoided an average of 75 hours per year in commute time. This not only increases productivity; it also reduces greenhouse gas emissions caused by commuting to the workplace.

The benefits of remote work aren't just for employees—companies can save an estimated \$1,400,000 per 100 employees per year by switching to remote work

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long term. For every part-time remote worker, organizations experience 21% higher profitability.

A remote workforce also allows businesses to re-evaluate their office space requirements. Reducing or eliminating space requirements saves on overhead expenses while reducing overall energy consumption.

## **Introduction**

"Going Green" is a rising trend establishing itself as the preferred way of doing things while saving the environment. This now appears in a large number of aspects in our lives, such as recycling, energy-efficient devices, clean energy sources, eco-friendly vehicles, green buildings.

Green computing is the environmentally responsible and eco-friendly use of computers and their resources. In broader terms, it is also defined as the study of designing, engineering, manufacturing, using and disposing of computing devices in a way that reduces their environmental impact. Green Computing, also known as Green Technology or Green IT, has quickly emerged as the most effective means of utilising technology.

Green Computing involves reducing the environmental impact of technology. That means using less energy, reducing waste and promoting sustainability. Green computing aims to reduce the carbon footprint generated by the Information Technology and Systems business and related industries. Energy-efficiency and e-waste are two major techniques involved in green computing. Energy efficiency involves implementation of energy-efficient central processing units (CPUs), servers and peripherals as well as reduced resource consumption. And e-waste is the proper disposal of electronic waste.

If we think computers are non-polluting and consume very little energy, in fact the use of computer plays a big role in environment pollution. It is estimated that out of \$250 billion per year spent on powering computers worldwide only about 15% of that power is spent computing, the rest is wasted idling (i.e. consumed by computers which are not in use but still turned ON). That consumed energy is the main reason of CO<sub>2</sub> emission, thus, energy saved on computer hardware and computing will equate tonnes of carbon emissions saved per year.

It started back in 1992, when the U.S. Environmental Protection Agency (EPA) launched the Energy Star program, a controlled labelling program to promote

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and recognise energy-efficiency. The Energy Star label has now certified more than 75 different product categories, homes, commercial buildings and industrial plants. The program has also resulted in the widespread adoption of sleep mode among electronics' consumers.

The goal of green computing is to attain economic viability and improve the way computing devices are used. Green computing practices include the development of environmentally sustainable production practices, energy efficient computers and improved disposal and recycling procedures. There are other goals of green information technology, most notably at the design and manufacturing stages. In all cases, four main aims are:

- to cut down to as little as possible the amount of energy used.
- to minimize the inclusion of harmful materials.
- to use as many biodegradable materials as possible.
- to extend as far as possible the life of the equipment.

Research continues into key areas such as making the use of computers as energy efficient as possible, and designing algorithms and systems for efficiency-related computer technologies.

To ensure that the goals of green information technology are achieved, the continuing efforts of developers, researchers, manufacturing companies and end users everywhere are necessary. A part is played in all this by education. A workforce and general public who have been made aware of the ecological issues of their computing choices are in the best position to help make IT greener.

"Going Green" is a rising trend establishing itself as the preferred way of doing things while saving the environment. This now appears in a large number of aspects in our lives, such as recycling, energy-efficient devices, clean energy sources, eco-friendly vehicles, green buildings.

Computing has also established its share to contribute to saving the environment under the concept "Green Computing". Green computing is the environmentally responsible and eco-friendly use of computers and their resources. In broader terms, it is also defined as the study of designing, engineering, manufacturing, using and disposing of computing devices in a way that reduces their environmental impact. Green Computing, also known as Green Technology or Green IT, has quickly emerged as the most effective means of utilising technology.

How Green Computing benefits the environment?

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### Why Green Computing?

If we think computers are non-polluting and consume very little energy, in fact the use of computer plays a big role in environment pollution. It is estimated that out of \$250 billion per year spent on powering computers worldwide only about 15% of that power is spent computing, the rest is wasted idling (i.e. consumed by computers which are not in use but still turned ON). That consumed energy is the main reason of CO<sub>2</sub> emission, thus, energy saved on computer hardware and computing will equate tonnes of carbon emissions saved per year.

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Following that, a large number of initiatives have been launched to promote Green Computing by the governments, industry and environmental NGOs. The IT industry is putting efforts in all its sectors to achieve Green Computing. Equipment recycling, reduction of paper usage, virtualisation, cloud computing, power management, green manufacturing are the key initiatives towards Green Computing.

A recent example is seen in Intel's 2030 strategy. Intel has been committed to continued progress on achieving net positive water use, 100% green power and zero waste to landfills across Intel's global manufacturing operations. Further, Intel has also included one highly unique component: "shared" climate and social goals - that require collaboration with industries, governments and communities. Simply stated, the goals are:

- Revolutionise health and safety with technology.

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- Make technology fully inclusive and expand digital readiness.
- Achieve carbon-neutral computing to address climate change.

Because "one company can't solve climate change" according to Intel CEO Bob Swan, Intel is marking a new era of shared corporate responsibility and collaboration. In the press release publicising the new initiative, Swan noted: *"The world is facing challenges that we understand better each day as we collect and analyse more data, but they go unchecked without a collective response - from climate change to deep digital divides around the world to the current pandemic that has fundamentally changed all our lives. We can solve them, but only by working together."*

Greening of technology has a potential role to play in enhancing environmental sustainability by making the entire product life cycle of technologies and products greener, including research, manufacturing, use and disposal.

- *Green design*: Designing energy-efficient computers, servers, printers, projectors and other digital devices.
- *Green manufacturing*: Minimising waste during the manufacturing of computers and other subsystems to reduce the environmental impact of these activities.
- *Green use*: Minimising the electricity consumption of computers and their peripheral devices and using them in an eco-friendly manner.
- *Green disposal*: Repurposing existing equipment or appropriately disposing of, or recycling, unwanted electronic equipment.

Green Computing has an optimistic future for saving the environment with ample avenues for making it possible. Hope we move forward with the goal of efficient computing while making the earth greener.

Green computing (also known as green IT or sustainable IT) is the design, manufacture, use and disposal of computers, chips, other technology components and peripherals in a way that limits the harmful impact on the environment, including reducing carbon emissions and the energy consumed by manufacturers, data centers and end-users. Green computing also encompasses choosing sustainably sourced raw materials, reducing electronic waste and promoting sustainability through the use of renewable resources.

The potential for green computing to have a positive impact on the environment is considerable. The information and communication technology (ICT) sector is

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responsible for between 1.8% and 3.9% of global greenhouse gas emissions. Moreover, data centers account for 3% of annual total energy consumption — an increase of 100% in the last decade.

“The energy demands and carbon output of computing and the entire ICT sector must be dramatically moderated if climate change is to be slowed in time to avoid catastrophic environmental damage,” according to a report published by the Association for Computing Machinery.

Every aspect of modern information technology — from the smallest chip to the largest data center — carries a carbon price tag, and green computing seeks to reduce that carbon price tag. Technology makers play a role in green computing, as do the corporations, organizations, governments and individuals that use technology. From massive data centers instituting policies to reduce energy consumption to individuals choosing to not use screen savers, green IT is multi-faceted and involves myriad decisions at every level.

Thousands of people are concerned about the same issues as water level begins to rise, glaciers melting, natural calamities like hurricanes and Tsunamis endangering lives, forests fires spreading, the ozone layer depleting, and the list is never-ending.

All these are the devastating effects of climate change and environmental degradation. Human activities are exhausting natural resources, emitting greenhouse gases, cutting down forests, and polluting land, water, and air.

That said, computers are part and parcel of our everyday lives, from children to the elderly. But they are also harmful to the environment from their manufacturing to usage and disposal. They consume lots of energy and emit carbon dioxide, and if you don't dispose of them properly or recycle them, they cause pollution.

This is where Green computing green IT comes into the picture. It is an effort to reduce or limit the harmful impacts of computing and implementing eco-friendly means on everyday usage.

In this article, I'll discuss green computing in detail, cover the challenges and benefits, and how you can implement green computing even at an individual level.

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## Objectives

In recent years focus of enterprises and technology firms has been shifted towards Green Computing rapidly. Green Computing discusses the options to support critical computing needs in sustainable manner by reducing strains on resources and environment. One of the main objectives of this study is to find out current trends on green computing, its implications, and the challenges for implementing green computing. This paper is organized as follows: next, section 2 reviews current trends in the field of Green Computing; section 3 will explore the challenges of Green Computing; section 4 will discuss the future trends towards Green Computing; and finally this study summarized the issues related to Green Computing and concludes.

## Literature Review

Data Centres have contributed a lot in making cloud computing powerful. Thus, there is an increasing demand for Data Centres and this will tend to increase in future as well. This increase in demand has increased the energy consumption by data centres. Hence, there is an utmost need to take sufficient measures to lower the risk factors associated with increased energy demand. The fundamental objective of this review is to analyse the various techniques that have been implemented so far to reduce the consumption of energy by cloud computing systems. These techniques mainly focus on the virtualization of machines that has proved the revolutionary application area of green IT.

**(Green cloud computing: A review on efficiency of data centres and virtualization of servers Published in: 2017 International Conference on Computing, Communication and Automation (ICCCA))**

Cloud computing itself is a much greener alternative to individual data centres with lesser number of servers being used and cloud data centres being far more efficient than those of traditional thereby reducing the carbon impact. Nonetheless, it cannot be neglected the fact that the data centres utilized by the cloud vendors are still a major source of carbon emissions due to the dirty energy usage. Therefore, the discussion of the paper is based on how green the foremost cloud providers are and the implementations of green IT attributes in the cloud infrastructure.

**(Green Cloud Computing: A Review on Adoption of Green-Computing attributes and Vendor Specific Implementations Published in: 2019**

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## **International Research Conference on Smart Computing and Systems Engineering (SCSE))**

Due to the large volume of data, high processing time, and power consumption, operators are looking for ways to reduce the energy consumption and subsequently optimize the energy consumption of data centers. Appropriate pricing of services and control of user demands along with considering renewable energy in the data center lead to a reduction in energy consumption of both users and data centers. The proposed methods for simultaneous reduction in the cost of energy consumption and an increase in the number of processed demands in data centers are not very practical. This paper proposed the capacity planning with dynamic pricing algorithm considering different factors in energy consumption reduction in green data centers of the fourth/fifth generation of mobile system networks delivering mobile cloud computing services. The proposed algorithm determines the optimal number of servers and addresses the trade-off between the cost of operation and the delay of services. A penalty function for cost was derived and various scenarios were designed and different qualities of services were considered using the Lyapunov optimization to set up the simulation environment. The provided results illustrate the efficiency of the proposed scheme and validate the mathematical model.

**(A Novel Cost Optimization Method for Mobile Cloud Computing by Capacity Planning of Green Data Center With Dynamic Pricing Published in: Canadian Journal of Electrical and Computer Engineering ( Volume: 42, Issue: 1, winter 2019))**

## **Research Methodology**

The overall goals of green computing are similar to that of any other ecologically-friendly endeavor: chiefly, to maximize energy efficiency, reduce the use of hazardous materials, and promote the recycling of obsolete products and waste. Various practices that deliver useful benefits have become popular. Energy management is often the starting point in implementation of green computing. In line with new ecological awareness, many companies have also come to accept that reduced energy consumption translates not only to reduced greenhouse gas emissions, but reduced operational costs for the business as well.

Fortunately, there are steps that can be taken to manage and reduce energy consumption. Servers and entire data centers can be consolidated. The data

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Green Computing – History, Methodologies, Benefits and Barriers 4 center can upgrade to energy-efficient servers and high efficiency power supplies, and can employ power management processes and controls that automatically turn off systems after set periods of inactivity. User computers are also high energy consumers. “Fifteen PCs can generate as much carbon emissions as a mid-size car each year. The average PC consumes 588 kilowatt-hours of electricity per year, and wastes almost 400 kWh of that by running at full-power when not in use. Using power management controls on PCs during periods of inactivity can cut energy use on average 60-70 percent” (Klustner, 2008).

Desktop computer power supply units (PSUs), which are generally inefficient and dissipate a certain amount of energy as heat, should be replaced with newer models. Virtualization, of both computer resources and the employee experience, has started to generate significant benefits for green computing. Computer virtualization refers to an abstraction of computer resources --- for example, running two or more logical computer systems on one set of physical hardware. With virtualization, hardware infrastructure is reduced, resulting in reduced energy and cooling consumption.

Cloud computing services, relating to the location and ownership of infrastructure, can be purchased from a third-party provider, resulting in economies of scale and significant cost savings. In addition to virtualization of computer resources, virtualization of the employee experience can also drive benefits for the environment, the company and the employee. Telecommuting, teleconferencing and telepresence technologies are good examples of this. These practices can reduce travel costs, increase worker satisfaction and, through a reduction of facilities requirements, reduce energy consumption and generate significant savings through lower overhead costs for office space, lighting, heat, and the like.

According to the EPA, the average annual energy consumption for U.S. office buildings is over 23 kilowatt hours per square foot, with heat, air conditioning and lighting accounting for 70% of all energy consumed (U.S. EPA, Office of Air and Radiation, 2008). Green Computing – History, Methodologies, Benefits and Barriers 5 Certainly one of the basics of green computing involves recycling. The EPA estimates that as of 2007, some 66 million PCs, 42 million monitors and 25 million printers/faxes/scanners were in storage. The EPA further estimates that only about 18% of these would be recycled, with the rest disposed of in landfills (Tucci, 2008). Recycling computer equipment can keep toxic materials such as lead and mercury out of landfills, and can also replace equipment that otherwise would need to be manufactured, thus reducing further energy requirements.

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Computer systems that have aged or become obsolete can have their lifecycles extended or re-purposed. For example, older servers can be kept powered off or in standby, and used only during periods of high demand. Older desktops can be used as terminal servers, or can be provided to employees whose jobs do not require high-end computing power. Older computer equipment can also be donated to various charities and non-profit organizations.

Finally, within the realm of green computing, there are many practices and work habits that can be encouraged, or mandated, among employees. Most computer equipment now comes with power management features and they should be activated. Computers, printers and monitors should be turned off when not in use. Printers, and hardcopy print output, can be especially hard on the environment. Users should review documents on screen, rather than printing documents unnecessarily, especially draft versions. Many printers can print double-sided documents, which is also environmentally friendly. Ink-jet printers, though a little slower than laser printers, use 80 to 90 percent less energy (“Go green, save green,” 2010). Many organizations mandate the recycling of paper, which is an excellent practice. Companies should carefully consider the size of computer monitors provided to employees. A large display device, such as a 17-inch monitor, uses 40 percent more energy than a 14-inch monitor. Also, if a monitor is set to display higher resolution, it requires more energy (“Go green, save green,” 2010).

- Purchasing from Environmentally Committed Companies
  - Participating in Electronic Recycling Programs
  - Deploying Virtual Technologies
  - Limiting Printing and Recycling Paper
  - Measurement of Current Carbon Footprints Produced by IT Components
  - Planning More Centralized IT Operations
  - Usage of More Efficient Computer Applications
  - Careful Weightage of Life-cycle of IT Devices and Accessories
  - We can put some simple efforts to save our environment: Modern OS implement ACPI (Advance configuration and power interface) in system which help in power saving and also allow you to program monitor and hard disk to power down after a particular period of inactivity.
  - Use virtualization technology: Green Computing: Barriers and Benefits 341 By using virtualization technology we can run multiple virtual machines on a single physical server.
  - Use energy star Labelled product: As energy labelled product are manufactured by keeping in mind green computing features like less
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power consumption and recyclable product. Then product automatically shut down when not in use specific time.

- Turn off your computer: Always remember to shut down your pc when it is not used otherwise it will consume large power and emit carbon dioxide.
- Use LCD rather than CRT: As liquid crystal display takes less power as compare to CRT. Less power consumption leads to less carbon dioxide.

## Findings

Whilst the performance and the breadth of application of computers is increasing, so too is our awareness of the cost and scarcity of the energy required to power them, as well as the materials needed to make them in the first place. However, because computing developments can enable individuals and businesses to adopt greener lifestyles and workstyles, in terms of the environmental debate computing is definitely both part of the problem and part of the solution. Through more environmentally aware usage (such as more effective power management and shut-down during periods of inactivity), and by adopting current lower power technologies, computers can already be made significantly more energy efficient. Indeed, just as we now look back and wonder why automobiles a decade or two ago used to guzzle so much petrol, in a decade's time we will no doubt be staggered that a typical desktop PC used to happily sit around drawing 100-200W of power every hour night and day, and when accomplishing no more than displaying a screensaver. The computing industry is more prepared and far more competent than almost any other industry when it comes to facing and responding to rapid change. Environmentally it is not a good thing that most PCs -- especially in companies -- have typically entered a landfill after only a few years in service. However, this reality does at least mean that a widespread mindset already exists for both adapting to and paying money for new computer hardware on a regular basis. Hence, whereas it took decades to get more energy efficient cars on the roads, it will hopefully only take a matter of years to reach a state of affairs where most computers are using far less power than they needlessly waste today. Product Longevity As per Gartner and Fujitsu reports on product life cycle it is obvious that the product durability and/or longevity are one of the best approaches towards achieving Green Computing objectives [13]. Long life of product will allow more utilization of products and it will put a control on unnecessary manufacturing of products. It is obvious that government regulations will push the products vendors to make more efforts to increase the product life. Technology is not a

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passive observer, but it is an active contributor in achieving the goals of Green Computing. IT industry is putting efforts in all its sectors to achieve Green computing. Equipment recycling, reduction of paper usage, virtualization, cloud computing, power management, Green manufacturing are the key initiatives towards Green computing. Current challenges to achieve Green Computing are enormous and the impact is on computing performance. Efforts of Governments and Non-Government Organizations (NGOs) are also appreciate-able. Government regulations are pushing Vendors to act green; behave green; do green; go green; think green; use green and no doubt to reduce energy consumptions as well. All these efforts are still in limited areas and currently efforts are mainly to reduce energy consumption, e-Waste but the future of Green Computing will be depending on efficiency and Green products. Future work in Green Computing discipline will also rely on research work in academics since this is an emerging discipline and there is much more need to be done. There is need for more research in this discipline especially within academic sector.

Current trends of Green Computing are towards efficient utilization of resources.

Energy is considered as the main resource and the carbon footprints are considered

the major threads to environment. Therefore, the emphasis is to reduce the energy

utilization & carbon footprints and increase the performance of Computing.

There are

several areas where researchers are putting lots of efforts to achieve desired results:

#### A. Energy Consumption

Organizations are realizing that the source and amount of their energy consumption significantly contributes to Greenhouse Gas (GhG) emissions. In response to this finding, organizations are currently using the following equation:

Reduced energy consumption = Reduced greenhouse gas emissions =

Reduced operational costs for the data center

It means adopting fewer and more energy efficient systems while refactoring application environments to make optimal use of physical resources is the best

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architectural model. According to Environmental Protection Agency in around 30% to 40% of personal computers are kept 'ON' after office hours and during the weekend and even around 90% of those computers are idle.

## B. E-Waste Recycling

Based on the Gartner estimations over 133,000 PCs are discarded by U.S. homes and businesses every day and less than 10 percent of all electronics are currently recycled.

Majority of countries around the world require electronic companies to finance and manage recycling programs for their products especially under-developed Countries.

Green Computing must take the product life cycle into consideration; from production to operation to recycling. E-Waste is a manageable piece of the waste stream and recycling e-Waste is easy to adopt. Recycling computing equipment such as lead and mercury enables to replace equipment that otherwise would have been manufactured.

The reuse of such equipments allows saving energy and reducing impact on environment, which can be due to electronic wastes.

## C. Data Center Consolidation & Optimization

Currently much of the emphasis of Green Computing area is on Data Centers, as the Data Centers are known for their energy hunger and wasteful energy consumptions.

United State Department of Energy (DoE) reported in its study in 2006 that United States data centers consumed 1.5% of all electricity and their demand is increasing by 12% per year and cost \$7.4 billion per year by 2011. According to DoE's current report in July 2011 Data Centers are consuming 3% of all US electricity and this consumption will double by 2015. With the purpose of reducing energy consumption in Data Centers it is worthwhile to concentrate on following:

needs are a key in building Green Data Centers. As per green computing best practices efficient servers, storage devices, networking equipments and power supply selection plays a key role in design of information systems.

Design process for data center cooling systems, it is significant to consider both current and future requirements and design the cooling system in such a way so it is expandable as needs for cooling dictates.

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Management and Cooling System.

electrical system equipment.

#### D. Virtualization

One of the main trends of Green Computing is virtualization of computer resources.

Abstraction of computer resources, such as the running two or more logical computer

systems on one set of physical hardware is called virtualization. Virtualization is a

trend of Green computing it offers virtualization software as well as management

software for virtualized environments. One of the best ways to go towards green and save enough space, enough resources, and the environment is by streamlining

efficiency with virtualization. This form of Green Computing will lead to Server

consolidation and enhance computer security. Virtualization runs fewer systems at

higher levels of utilization. Virtualization allows full utilization of computer resources

and benefits in:

- Reduction of total amount of hardware;
- Power off Idle Virtual Server to save resources and energy; and
- Reduction in total space, air and rent requirements ultimately reduces the cost

#### E. IT Products and eco-labelling

Another approach to promote Green Computing and save environment is to introduce

policies all around the World, so that, companies design products to receive the eco-

products. These organizations provide certificates to IT products based on factors

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including design for recycling, recycling system, noise energy consumption etc.

## **Conclusion**

Despite the barriers, green computing is gradually becoming more popular. In most commercial endeavours, consumers are increasing the demand for eco-friendly products. There is a vast amount of computer equipment manufactured worldwide. This, coupled with the widespread use of information technology has had a direct impact on the environment.

The goal of green computing is to reduce the negative impact of computer resources on our natural resources. To accomplish this, companies that implement green computing purchase and deploy information technology equipment that is manufactured with environmentally-friendly chemicals and materials. They deploy computer equipment that uses less energy, and they utilize processes to positively manage energy consumption.

Companies are moving to various methods of virtualization that require less computer resources to accomplish the same tasks. They attempt to recycle or re-purpose obsolete computer equipment, or to dispose of the equipment in an ecologically-sensitive manner when the equipment cannot be recycle. These companies also encourage their employees to adopt habits and practices that help to reduce the organization's environmental footprint. Organizations that have adopted green computing methods demonstrate how Green IT can reduce costs in a company, and increase the profit margin. Additionally, if a company demonstrates corporate responsibility and is perceived by the public as being environmentally responsible, this can attract more customers and increase revenue. "Sustainability, corporate responsibility, and greening business practices have jumped from social movement to business imperative. Green IT is a dynamic, strategic, and ethical framework of practice for all IT. Green IT is about doing what it takes to be innovative, agile, efficient, responsive, profitable and responsible all at the same time" (Baroudi, Hill and Reinhold, 2009).

It can be seen that green computing is very necessary for protecting our environment. As the time increase the need of computers increase very fastly so that need of green computing also becomes very necessary. There are various advantages and disadvantages of green computing but as comparisons to barriers the advantages are more that's why need of green computing is important. In this paper we conclude that green computing is very important for neat and clean environment.

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## Limitations

According to researchers in the past the focus was on computing efficiency and cost associated to IT equipments and infrastructure services were considered low cost and available. Now infrastructure is becoming the bottleneck in IT environments and the reason for this shift is due to growing computing needs, energy cost and global warming. This shift is a great challenge for IT industry. Therefore now researchers are focusing on the cooling system, power and data center space. At one extreme it is the processing power that is important to business and on the other extreme it is the drive, challenge of environment friendly system, and infrastructure limitations. Green Computing challenges are not only for IT equipments users but also for the IT equipments Vendors. Several major vendors have made considerable progress in this area, for example, Hewlett-Packard recently unveiled what it calls —the greenest computer ever— the HP rp5700 desktop PC. The HP rp5700 exceeds U.S. Energy Star 4.0 standards, and has an expected life of at least five years, and 90% of its materials are recyclable. Dell is speeding up its programs to reduce hazardous substances in its computers, and its new Dell OptiPlex desktops are 50% more energy-efficient than similar systems manufactured in 2005, credit goes to more energy-efficient processors, new power management features, and other related factors. IBM is working on technology to develop cheaper and more efficient solar cells plus many other solutions from IBM to support sustainable IT.

According to researchers of Green Computing following are few prominent challenges that Green computing is facing today: □ Equipment power density / Power and cooling capacities; □ Increase in energy requirements for Data Centers and growing energy cost; □ Control on increasing requirements of heat removing equipment, which increases because of increase in total power consumption by IT equipments; □ Equipment Life cycle management – Cradle to Grave; and □ Disposal of Electronic Wastes.

1. Return of Investment The major problem was educating the stakeholders regarding the environmental impact of computers. For a project that involves Greening, the returns are generally seen after a long period of time. Hence an important challenge in this project was to show immediate returns after the successful implementation of Green IT in the computer center.
  2. New Optimization Techniques in Performance-Energy-Temperature aware Computing The exponential growth in computing activity and the rising concern for energy conservation have made energy efficiency in computers a technological issue of prime importance. The tradeoff between Performance-Energy-Temperature has to be made so
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that the maximum benefits can be achieved. Designing techniques that are optimal with respect to performance, energy, and temperature are of utmost requirement as far as green computing research challenges are concerned.

3. Disposal of Electronic Wastes Reliability about the use of green materials in computer is perhaps the biggest challenge that the electronics industry is facing. Electronics giants are about to roll out eco-friendly range of computers that aim at reducing the e-waste in the environment. They are likely to be free of hazardous materials such as brominated flame-retardants, PVCs and heavy metals such as lead, cadmium and mercury, which are commonly used in computer manufacturing.
4. 4. Perspective with respect to Indian Scenario In India, the implementability of principle of “Green Computing” is facing a dilemma due to many socio-economic matters and those are linked to be sougheed out to pull India in the mainstream movement of “Green Computing”. Lack of basic research initiative and congenial infrastructure has resulted in absence of good patents and commercial production of indigenously built equipments.
5. 5. Power Consuming Leaderships in the field are trying to find a generation of IC chips that have high efficiency and give higher performances without consuming too much power but this is not a simple process, it takes a huge effort, amount of a lot of time, and needs high levels of skilled engineers to reach and achieve this goal. 6. Increase in energy requirements Some people need or prefer to use high processors to achieve their tasks. However, these requirements need a great amount of power with the green computers with the same specifications considered extremely expensive.

There are many benefits to green computing. Unfortunately, there are barriers that a company has to overcome in order to successfully implement green computing. First is the natural psychological resistance to change on the part of any organization. The larger the organization, the more difficult it is to justify and manage change. Green computing can justify some significant cost savings and increased profits, but there are also “soft benefits,” such as environmental awareness, that are more difficult to recognize and quantify. Cloud computing is difficult for many companies to embrace as they apparently still feel the need to “own” the infrastructure and resources, rather than “rent” them from a third-party provider (Barnhart, n.d.). Another overwhelming barrier can be that of cost. Most companies, particularly in times of a weaker economy, find it hard to justify expenditures on information technology, which is often viewed as a cost center, rather than a business enabler. It can be very challenging to construct a cost-benefit analysis that adequately demonstrates how information technology

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contributes to the bottom line. Certainly, a comprehensive return-on-investment analysis that shows how, for example, reduced energy or travel costs can increase the profit margin, is imperative. Internal recycling, or re-purposing of computer equipment, can also contribute to cost reductions and thus improved profit margins. Many states have enacted specific laws relating to the disposal of certain types of electronic equipment in landfills, and companies view this as a cost increase, rather than a cost reduction. Green computing is still relatively new and it is not easy for organizations to understand and articulate their requirements. Although it is desirable to purchase computer equipment from suppliers and vendors that are ecologically mindful in their manufacturing processes, this can be challenging to accomplish as many manufacturers lack environmental awareness.

In achieving Green Computing, the main security threat is managing Techno trash that is also known as E-waste or E-trash. Techno trashes are electronic gadgets or part of them those are not used anymore or replaced with some other devices. It is noticeably important that we, the users, help in recycling them. The peripherals are made up of few hazardous elements. And it is important that they are recycled properly in order to avoid the greenhouse effects. As mentioned earlier, when these are buried under ground they contaminate ground and ground water and moreover they are non-degradable elements which may also affect the ground water level as it becomes difficult for rain water to penetrate further.

Global warming is an important threat to the world because of greenhouse effects. Greenhouse gasses are also produced by these toxic e-wastes. Electronic gadgets, nowadays, work efficient and faster. The main issue with them is that they produce more heat with greenhouses gasses, such as Carbon monoxide, Carbon dioxide etc.

Electricity consumption in ICT (i.e. Information and Communications Technology) is another notable area to concentrate. Carbon emission also has to be considered. The heat produced by computing devices has to be reduced or controlled. Carbon emission, heat production and more electricity consumption are very most important areas that obstacles in achieving green computing.

## **Future Scope**

As discussed earlier the reason for shift is because of growth in computing needs, energy cost and global warming and this shift is great challenge for IT industry. The future of Green Computing is going to be based on efficiency,

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rather than reduction in consumption [10]. The primary focus of Green IT is in the organization's self interest in energy cost reduction, at Data Centers and at desktops, and the result of which is the corresponding reduction in carbon generation. The secondary focus of Green IT needs to focus beyond energy use in the Data Center and the focus should be on innovation and improving alignment with overall corporate social responsibility efforts. This secondary focus will demand the development of Green Computing strategies. The idea of sustainability addresses the subject of business value creation while ensuring that long-term environmental resources are not impacted. There are few efforts, which all enterprises are supposed to take care of [2]:

## Certifications

There are several organizations providing certificates to green technology. Vendors are based on their product quality, material, life of the product and recycling capabilities. In future such certifications together with recommendations and government regulations will put more pressure on vendors to use green technology and reduce impact on environment.

**Cloud Computing** Cloud Computing has recently received significant attention [11], as a promising approach for delivering Information and Communication Technology services by improving the utilization of Data Center resources.

In principle, cloud computing is energy-efficient technology for ICT [12] provided that its potential for significant energy savings that have so far focused on only hardware aspects, can be fully explored with respect to system operation and networking aspects also. Cloud Computing results in better resource utilization, which is good for the sustainability movement for green technology.

**Leveraging Unused Computer Resource** One of the exiting areas where Green Computing can grow is the share and use efficiently the unused resources on idle computers. Leveraging the unused computing power of modern machines to create an environmentally proficient substitute to

traditional desktop computing is cost effective option. This makes it possible to reduce CO<sub>2</sub> emissions by up to 15 tons per year per system and reduce electronic waste by up to 80% [14].

**F. Data Compression** In enterprise, huge amount of data that is stored is somehow or other duplicated information. Information System backups are true example of such duplicated data. Intelligent compression techniques can be used to compress the data and

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eliminate duplicates help in cutting the data storage requirements.

G.Applications Green Computing is a diverse field and due to its nature and priority from all fields of life Green Computing has applications in every sector of computing as the goal is to save the environment and ultimately the life.

The current main applications of Green Computing are covering following computing sectors [15]: · Equipment design; · Equipment recycling; · Data Center optimization and consolidation; · Virtualization; · Paper free environment; · Application Architecture; and · Power Management

- **Green Use**

Reducing the power usage of computers and its periphery subsystems and using them in an eco-friendly manner. Also adopting virtualization reducing the need of energy.

- **Green Disposa**

Recycling and reusing existing equipment, properly disposing the wasted IT/computing materials, electronic equipment etc.

- **Green Design**

Designing energy efficient as well as effective systems which have a minimal impact on the green environment.

- **Green manufacturing**

Manufacturing Biodegradable materials, also manufacturing long usable, recyclable products and reducing wastage during manufacturing process.

- **Green use** reducing the energy consumption of computers and other information systems as well as using them in an environmentally sound manner.

- **Green disposal** refurbishing and reusing old computers and properly recycling unwanted computers and other electronic equipment.

- **Green design** designing energy-efficient and environmentally sound components, computers, servers, cooling equipment, and data centers.

- **Green manufacturing** manufacturing electronic components, computers, and other associated subsystems with minimal impact on the environment.

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## METHODS TO IMPLEMENT GREEN COMPUTING

- Carbon Free Computing

Carbon Free Computing is a project started by VIA technologies in October 2006 as part of the VIA Green Computing Initiative, which aims to manufacture the world's first line of PC products that can be certified carbon free. The VIA Carbon Free Computing initiative consists of a set of programs and products that are developed to reduce their impact on the environment.

- Solar Computing

The need today is to run computers in every corner of the country. Government, BFSI, Education and FMCG, all sectors depend on ICT for effective execution. However, the power situation in India does not permit the use of computers in large parts of rural India. SPV based solar power generation has emerged as a reliable and efficient power source for those locations that are not connected to the electricity grid. Thinvents solar computing solution is designed specifically to allow computers to be run from SPV based solar power.

In this document, we will study some of the facets of a solar computing system. We will also see how such a system is different from an ordinary PC connected to a solar power generator. Briefly, a solar computing solution should:

Run from the direct current generated by SPV and battery, not alternating current.

Be highly energy efficient and low power, since solar power is still quite expensive.

Be lightweight, rugged and reliable, to reduce transport and service costs.

Be able to operate in a hot and dusty environments.

- Quiet computing

When we talk with people about quiet computers, many don't understand what we mean right off the bat. However, when they think about that constant hum that comes from their desktop, the desire to have more peace and quiet is quite attractive. Puget Systems has become an industry leader in the design of quiet computer systems and has even been able to get certain high performance configurations to operate under the level of human hearing limits.

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- **ADVANTAGES OF GREEN COMPUTING**

Reduced energy usage from green computing techniques translates into lower carbon dioxide emissions, stemming from a reduction in the fossil fuel used in power plants and transportation.

Conserving resources means less energy is required to produce, use, and dispose of products.

Saving energy and resources saves money.

Green computing even includes changing government policy to encourage recycling and lowering energy use by individuals and businesses.

Reduce the risk existing in the laptops such as chemical known to cause cancer, nerve damage and immune reactions in humans.

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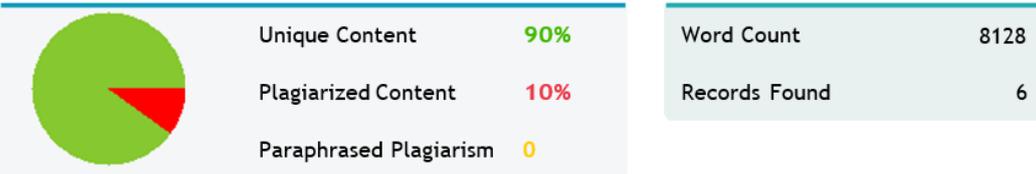
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## **Acceptance Letter**

**Dated: 13/05/2022**

Dear Authors,

We are glad to inform you that your paper has been accepted as per our fast peer review process:

**Authors Name: Yatindra Chaturvedi**

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**Paper Status: Accepted**

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