# GREEN COMPUTING: APPROACHES, TECHNIQUES AND ITS IMPLEMENTATION

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**Abstract: Green computing or green technology is a buzzword in the IT industry that refers to the potential environmental benefits cloud-based services can offer society. It is environmental sustainable to the use of computers and other related peripheral devices like – hardware devices, storage devices, communication devices and especially networking devices as interconnection of these devices helps in the formation of clouds and leads towards more consumption of power in the form of electricity. Green computing leads towards effective and efficient use of resources with minimum or no harm to the sustainability of environment. The term green computing combines two words: green, which means environmentally friendly, and cloud computing, which is the delivery of IT services over the internet. The main goal of green cloud computing is to reduce the consumption of nonrenewable resources and promote recyclability and renewability of used, outdated, factory or electronic waste products. Now a day's computers – system, laptop, ipads, notepad, tablets, smartphones, and smart watches are being used by every individual not only for their official use but for personal use as well. This increasing number of systems are leading towards production of more electronic devices which in turn will leads to more power consumption for their efficient working. As the power which we usually opt for our devices functionality is turned up by 75% of nonrenewable resources; increasing demand for such appliances will directly affect our environment. More amount of electricity consumption will increase carbon content in the atmosphere. Sudden increase in demand of systems is becoming a problematic situation not only for environment protectors but for everyone. This problem is being noticed by people and trails are being taken in this field to reduce the power usage of systems. Green computing will work in this field as a life saver to environment as green computing will reduce energy usage by using various green computing eco-friendly approaches like – green design, green awareness, green standards, green disposals, green manufacturing and green usage which therefore help in the less emission of carbon dioxide in the atmosphere and also will put a halt on consumption of fossil fuels used in power plants, shipping, heating, industries, manufacturing units. Green Cloud computing is envisioned to achieve not only efficient processing and utilization of computing infrastructure, but also minimize energy consumption. This is essential for ensuring that the future growth of Cloud computing is sustainable. Green computing includes changes in environment policies to boost recycling, virtualization, multi-tenancy and consolidation. Green cloud computing is reducing consumption of energy by personages or business.**

***Keywords: Green computing, Eco-friendly approaches, Sustainable environment, Recycling, Multi-tenancy, Virtualization, and Consolidation.***

## 1. Introduction:

The concept of green computing has begun to spread in the past few years, gaining increasing popularity. The rationale behind energy efficient coding is to save power by getting software to make less use of the hardware, rather than continuing to run the same code on hardware that uses less power. Now a days IT sector production houses have arisen to emphasize that successful green is in their greatest attention, together in standings of open dealings and cheap costs.

In 1992, the U.S. Environmental Protection Agency launched Energy Star, a voluntary labeling program that is designed to promote and recognize energy-efficiency in monitors, computer systems, climate control equipment, and other related technologies. The main resultant of this program was sleep mode concept i.e consumers started adoption of sleep mode for their electronic appliances while not in use. Concurrently, the Swedish organization TCO Development launched the TCOCertification program to promote low magnetic and electrical emissions from CRT-based computer displays; this program was later expanded to include criteria on energy consumption, ergonomics, and the use of hazardous materials in construction. A huge crowd who attended the program later become efficient promoters and leaders for spreading message on energy consumption in a defined and efficient manner.

Green computing includes two primary techniques: Energy efficiency and Electronic-waste. Reduced resource usage and energy efficiency (CPUs), servers, and peripherals are all energy efficient. Nowadays, modern technology is based on a diverse set of hardware, complex systems, and networks, as well as human interaction. Green computing initiatives must cover all sectors, starting from a projection of a product until its disposal, in order to achieve a greener computing environment. A solution may also need to address end user satisfaction by appropriate user experience of the same filed, management, restructuring, regulatory compliance, and return on investment.

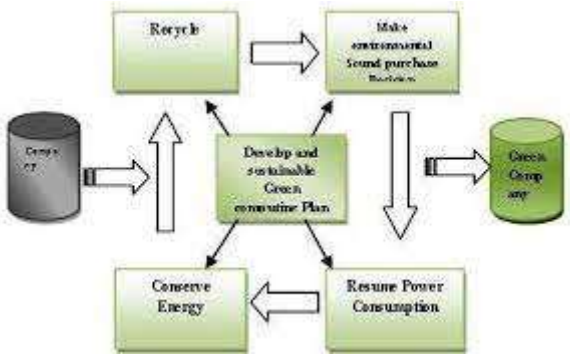



**Figure 1 : Green computing framework**

Green computing can be defined as the ecologically responsible and eco-friendly use of computers and their resources. Going green is becoming more popular as a way to save the environment from pollution and another way of nature degrading. The manufacturing and use of technology can result in air, water, heat, and noise pollution.

## 2. Techniques

In general, there are four main techniques to pursue a green computing environment;

- **Green usage**: reducing the amount of electricity used by computers and their peripheral devices and using them in an eco-friendly manner.
- **Green disposal:** repurposing old technology or properly discarding or recycling obsolete electronic equipment are both viable options.
- **Green design**: Designing energy-efficient computers, servers, printers, projectors, and other digital devices is considered a sustainable and green design.
- **Green manufacturing**: From the early phases it's important to choose the right material. Hazardous materials should be avoided, directly affecting reducing the environmental impact of waste equipment when becomes obsolete.

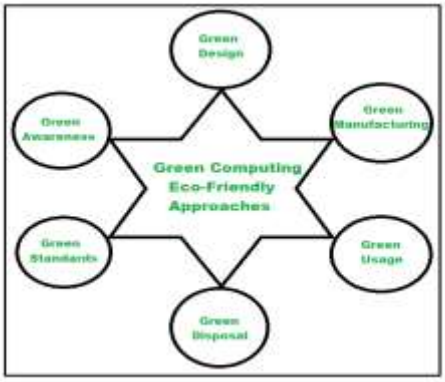



**Figure 2 : Green computing techniques**

## 3. Approaches:

### *i) Product longevity:*

Gartner maintains that in the life cycle of a PC 70% of the natural resources are used for PC manufacturing process. More recently, Fujitsu released a Life Cycle Assessment (LCA) of a desktop that show that manufacturing and end of life accounts for the majority of desktop's ecological footprint. Therefore, the biggest contribution to green computing usually is to prolong the equipment's lifetime.

### *ii) Data center design:*

Energy efficient data center design should consider all important aspects of energy use included in a data center: including the IT equipment, HVAC equipment, actual location, configuration and construction of the building.

Five primary best practices areasto focus energy efficient data center design:

a. Consolidate lightly utilized servers and utilize built-in server power management features.
b. Implement efficient data storage measures
c. Energy monitoring software
d. Cooling systems instead of energy intensive air conditioners and manage airflow for cooling efficiency.
e. Reduce energy losses from UPS systems.

***iii) Virtualization:***

Virtualization relies on software to simulate hardware functionality and create a virtual computer system. This enables IT organizations to run more than one virtual system – and multiple operating systems and applications – on a single server. The resulting benefits include economies of scale and greater efficiency. The concept originated with the IBM mainframe operating systems of the 1960s, but was commercialized for x86-compatible computers only in the 1990s. With virtualization, a system administrator could combine several physical systems into virtual machines on one single, powerful system, thereby unplugging the original hardware and reducing power and cooling consumption. Several commercial companies and open-source projects now offer software packages to enable a transition to virtual computing. Intel Corporation and AMD have also built proprietary virtualization enhancements to the x86 instruction set into each of their CPU product lines, in order to facilitate virtualized computing.

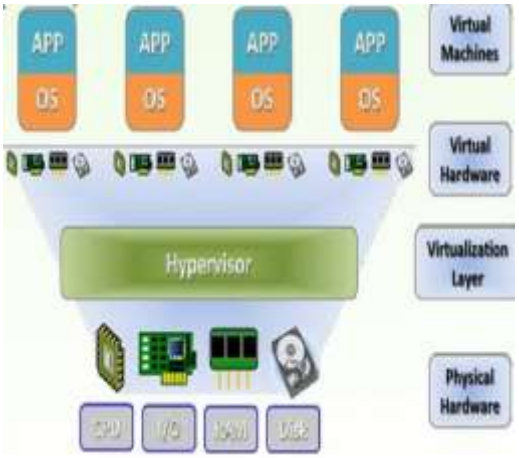



**Figure 3 : Virtualization**

***iv) Terminal Servers:***

Terminal servers have also been used in green computing methods. Terminal Services for Windows and the Aqua Connect Terminal Server for Mac, both deliver operating systems to end users. Using this method, users terminal in to a central server. There has been an increase in using terminal services with thin clients to create virtual labs. Thin clients use up to 1/8 the amount of energy of a normal workstation. Using thin clients with a terminal server delivers the Windows or Mac operating system to end users while also decreasing energy costs and consumption.

***v) Power Management:***

Power management is a feature that efficiently manages and optimizes the power consumption of computer hardware thereby saving money and energy. Green Computing refers to the efficient use of computer resources using a computer power management software.

The Advanced Configuration and Power Interface (ACPI), an open industry standard, allows an operating system to directly control the power saving aspects of its underlying hardware. This allows a system to automatically turn off components such as monitors and hard drives after set periods of inactivity. In addition, a system may hibernate, where most components (including the CPU and the system RAM) are turned off. ACPI is a successor to an earlier Intel-Microsoft standard called Advanced Power Management, which allows a computer's BIOS to control power management functions.

***vi) Power Supply:***

A power supply unit (PSU) converts mains AC to low-voltage regulated DC power for the internal components of a computer. Modern personal computers universally use switched-mode power supplies. Some power supplies have a manual switch for selecting input voltage, while others automatically adapt to the mains voltage. Desktop computer power supplies (PSUs) are generally 70–75% efficient, dissipating the remaining energy as heat. As of July 20, 2007, all new Energy Star 4.0-certified desktop PSUs must be at least 80% efficient.

***vii) Storage:***

Smaller form factor (e.g. 2.5 inch) hard disk drives often consume less power per gigabyte than physically larger drives. Unlike hard disk drives, solid-state drives store data in flash memory or DRAM. With no moving parts, power consumption may be reduced somewhat for low capacity flash based devices. Even at modest sizes, DRAM based SSDs may use more power than hard disks, (e.g., 4GB i-RAM uses more power and space than laptop drives). Flash based drives are generally slower for writing than hard disks.

As hard drive prices have fallen, storage farms have tended to increase in capacity to make more data available online. This includes archival and backup data that would formerly have been saved on tape or other offline storage. The increase in online storage has increased power consumption. Reducing the power consumed by large storage arrays, while still providing the benefits of online storage, is a subject of ongoing research.

***viii) Display:***

LCD monitors typically use a cold-cathode fluorescent bulb to provide light for the display. Some newer displays use an array of light-emitting diodes (LEDs) in place of the fluorescent bulb, which reduces the amount of electricity used by the display.

**ix) Operating System Issues:**

Microsoft has been heavily criticized for producing operating systems that, out of the box, are not energy efficient. Due to Microsoft's dominance of the huge desktop operating system market this omission may have resulted in more energy waste than any other initiative by other vendors. Microsoft claim to have improved this in Vista. This claim is disputed in the community. This problem has been compounded because Windows versions before Vista did not allow power management features to be configured centrally by a system administrator. This has meant that most organizations have been unable to improve this situation.

Again, Microsoft Windows Vista has improved this by adding basic central power management configuration. The basic support offered has been unpopular with system administrators who want to change policy to meet changing user requirements or schedules. Several software products have been developed to fill this gap.

***x) Materials Recycling:***

Computer systems that have outlived their particular function can be repurposed, or donated to various charities and non-profit organizations. However, many charities have recently imposed minimum system requirements for donated equipment. Additionally, parts from outdated systems may be salvaged and recycled through certain retail outlets and municipal or private recycling centers.Recycling computing equipment can keep harmful materials such as lead, mercury, and chromium out of landfills, but often computers gathered through recycling drives are shipped to developing countries where environmental standards are less strict than in North America and Europe. The Silicon Valley Toxics Coalition estimates that 80% of the post-consumer e-waste collected for recycling is shipped abroad to countries such as China, India, and Pakistan.

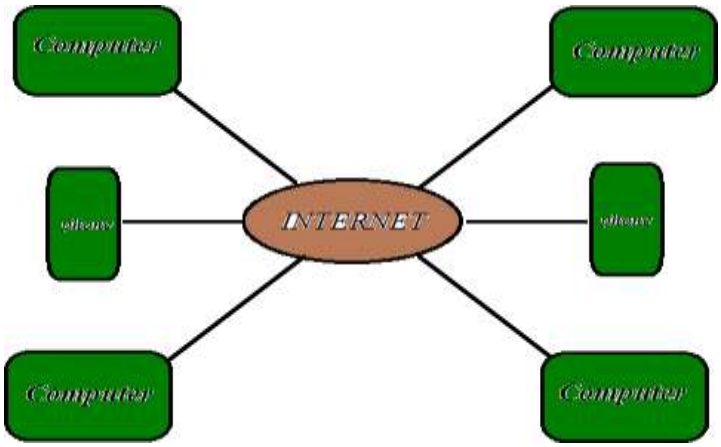
Computing supplies, such as printer cartridges, paper, and batteries may be recycled as well.


**Figure 4 : Material Recycling**

***xi) Telecommuting:***

Telecommuting (also known as teleworking) refers to the act of completing work assignments from a location other than an office via an internet and phone connection. These technologies are often implemented in green computing initiatives. The advantages of using these techniques in green computing are : increased worker satisfaction, reduction of greenhouse gas emissions related to travel, and increased profit margins as a result of lower overhead costs for office space, heat, lighting, etc. The savings are significant; the average annual electricity consumption for space conditioning and lighting in India is around 80 KWh/m2 and 160 KWh/m2 for residential and commercial buildings respectively.
Voice over IP (VoIP) reduces the telephony wiring infrastructure by sharing the existing Ethernet copper. VoIP and phone extension mobility also made hot desking and more practical.

**Figure 5 : Telecommunication network devices energy indices**




The information and communication technologies (ICTs) energy consumption, in the USA and worldwide, has been estimated respectively at 9.4% and 5.3% of the total electricity produced. The energy consumption of ICTs istoday significant even when compared with other industries.

**Conclusion:** Green Computing is not only a new trend; it is a technology of itself. Using Virtualization one can prevent IT systems from failing. A virtual machine will also help to protect your IT environment from bugs, viruses, and crashes when you are testing software or trying out a new program. Green computing is used to increase sustainability in your data center and decrease your organization's carbon footprint. It is not only a step toward an eco-friendly environment but green computing also leads towards less usage of energy for producing, using, and disposing of products, which translates into lower carbon dioxide emissions. It helps in saving energy and resources saves money as a result of more efficient computing and running software. It is also enhancing and sophisticating the government policy to encourage recycling and use eco-friendly sources of energy and reduce the harmful health effects from the risks that exist in the laptops, such as chemicals known to help cause cancer and other immune reactions in humans.

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