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Green Computing

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Abstract - Green computing refers to the practice and procedures of using computing resources in an environment friendly way while maintaining overall computing performance. Global warming is the continuing rise in the average temperature of the Earth's climate system due to a range of factors. Scientific understanding of the various

causes of global warming has been increasing since the last decade. Climate change and associated impacts vary from region to region across the globe. Nowadays, weather behavior is becoming extremely unpredictable throughout the globe. United Nations Framework Convention on Climate Change (UNFCCC) is working relentlessly to achieve its objective of preventing dangerous anthropogenic (human- induced) climate change.

Owing to global warming, various regulations and laws related to environmental norms forces manufacturers of I.T equipment's to meet various energy requirements. Green computing is a well-balanced and sustainable approach towards the achievement of a greener, healthier and safer environment without compromising technological needs of the current and future generations. This paper is a survey of several important literature related to the field of green computing that emphasizes the importance of green computing for sustainable development.

Keywords –Green computing, environment, global warming

I. INTRODUCTION

Green computing, Green ICT as per IFG International Federation of Green ICT and IFG Standard, green IT, or ICT sustainability, is the study and practice of environmentally sustainable computing or IT [1]. San Murugesan [2] notes that Green IT "is the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems—such as monitors, printers, storage devices, and networking and communications systems — efficiently and effectively with minimal or no impact on the environment".

Murugesan [2] lays out the following four paths along which he believes the environmental effects of computing should be addressed:

1. Green Use: Reducing the energy consumption of computers and other information systems as well as using them in an environmentally sound manner.
2. Green Disposal: Refurbishing and reusing old computers and recycling unwanted computers and other electronic equipment.
3. Green Design: Designing energy efficient and environmentally sound components, computers, servers and cooling equipment's.
4. Green Manufacturing: Manufacturing electronic components, computers and other associated sub systems with minimal impact or no impact on the environment.

These four paths cover a number of central areas and activities such as: design for environmental sustainability energy-efficient computing power management data center design, layout and location, server virtualization, responsible disposal and recycling regulatory compliance green metrics, assessment tools and methodology, e n v i r o n m e n t - related r i s k m i t i g a t i o n u s e of renewable energy sources and eco-labelling of IT products. Green computing is all about the efficient use of computers and computing [3].

Green computing can also develop solutions that offer benefits by "aligning all IT processes and practices with the core principles of sustainability, which are to reduce, reuse, and recycle; and finding innovative ways to use IT in business processes to deliver sustainability benefits across the enterprise and beyond" [4].

The goals of green computing are quite similar to green chemistry which are to reduce the use of hazardous materials, maximize energy efficiency during the product's lifetime, and promote the recyclability or biodegradability of non-operational products and factory waste [1].IT departments of many corporate are investing both time and money in green computing initiatives to reduce the environmental impact of their IT operations.

II. SURVEY OF LITERATURE

In this section a survey of some very important literature on green computing is carried out under the following subheadings.

A. Environment And I.T

Widespread use of computers and related IT products has a very bad effect on the environment. Various environmental issues and problems due to the impact of I.T on environment are discussed below:

I) **Environmental issues:** As we all know greenhouse gases are having a devastating and long-lasting harmful effect on our atmosphere and environment. The growing accumulation of greenhouse gases is changing the world's climate and weather patterns in an alarming way. Accumulation of greenhouse gases in the atmosphere is slowly increasing global

temperature. Global data shows that storms, droughts, and other weather-related disasters are growing more severe and occurring more frequently than ever before. Electricity is a major cause of climate change, because the thermal power plants that help generate electricity also releases huge amount of carbon dioxide and many other harmful particles into the atmosphere. These emissions cause serious respiratory diseases, smog, acid rain and global climate change. Reducing electric power consumption and producing electricity in more eco-friendly way is a key to reduce carbon dioxide emissions and their impact on our environment and global warming [2].

More importantly weather behavior to a large extent has become unpredictable. The sea level is also increasing alarmingly because due to global warming the arctic glaciers are melting as never before. Leaders of all countries are very much worried and keen to stop the accumulation of greenhouse gases in the atmosphere. They are of the opinion that global emissions of greenhouse gases would have to stop growing to curb the menace of greenhouse effect.

II) **Impact of I.T on environment:** IT affects our environment in different ways. Each stage of a computer's life, starting from its production, throughout its use, and into its disposal, poses environmental problems.

Manufacturing computers and their various electronic and non-electronic components consumes electricity, raw materials, harmful chemicals and water and generates hazardous waste. All these directly or indirectly increase carbon dioxide emissions and impact the environment. The total electrical energy consumption by servers, computers, monitors, data communication equipment's, and cooling systems for data centers number of old computers, monitors, and other electronic equipment few years after purchase, and most of this ends up in landfills, polluting the earth and contaminating water due to the presence of various toxic materials in the electronic components. The increased number of computers and their use, along with their frequent replacements, make the environmental impact of IT a major concern for all of us. Consequently, there is increasing pressure on all stake holders—the IT industry, businesses, and individuals—to make IT environmentally friendly throughout its lifecycle, from birth to death to rebirth. It is our collective responsibility to safeguard our environment for our future generations [2].

B. Green I.T Advantages

The following are some of the advantages of green I.T:

1.Enterprises with the technology and vision to produce products and services that address environmental issues enjoy a competitive edge because many customers when making purchasing, leasing, or outsourcing decisions, have started to consider the service providers' environmental records and initiatives [2].

2.Organizations face lower energy costs and even save a lot on government taxes when they follow government policies on environment and produce goods following strict environment norms.

3. Investors and consumers are beginning to demand more disclosures from companies with regard to their carbon footprint as well as their environmental initiatives and achievements, and they have started discounting share prices of companies that poorly address the environmental problems they create. As a result of which, many businesses have begun showing their environmental credentials. For instance, the Carbon Disclosure Project [5] is a recent initiative to request global companies to disclose their carbon emissions [2].

C. Adoption of Green Computing

The following factors are impacting data centers as well as desktop computers, though to a lesser degree, and driving the need to adopt green computing practices [6]: *I)* **Rapid Growth of The Internet:** More and more people are increasingly relying on electronic data. There has been a rapid adoption of internet communications and media, computerization of business processes and applications, legal requirements for record retentions and disaster recovery. All these have led to the rapid growth in the size and number of data centers. On an individual level video and music downloads, on-line gaming, social networking site visits and VoIP are key drivers. Industry is also using internet increasingly. Internet usage is growing at more than 10 percent annually leading to an estimated 20% CAGR in data center demand [7]. Disaster recovery strategies that emphasizes on maintaining duplicate records increases demand further. Many federal, state, and local government agencies have adopted e-government strategies that utilize the Web for public information, reporting, transactions, homeland security, and scientific computing [8].

II) **Increasing Equipment Power Density**: Although advances in server CPUs have in some cases enabled higher performance with less power consumption per CPU, overall server power consumption has continued to increase as more servers are installed with higher performance power-hungry processors with more memory capacity [9], [10]. As more servers are installed they require more floor space. To pack more servers in the same footprint the form factor of servers has become much smaller, in some cases shrinking by more than 70% through the use of blade servers. This increase in packaging density has been matched by a major increase in the power density of data centers. Density has increased more than ten times from 300 watts per square foot in 1996 to over 4,000 watts per square foot in 2007, a trend that is expected to continue its upward spiral [8], [9], [10], [11].

III) **Increasing Cooling Requirements:** The increase in server power density has led to an associated increase in data center heat density. Servers require approximately 1 to 1.5 watts of cooling for each watt of power used [12], [13], [14]. The ratio of cooling power to server power requirements will continue to increase as data center server densities increase.

IV) **Increasing Energy Costs:** Data center expenditures for power and cooling can exceed that for equipment over the useful life of a server. One study estimated that for a typical $4,000 server rated at 500 watts, it would consume approximately $4,000 of electricity for power and cooling over three years, at

$0.08 per kilowatt-hour, and double that in Japan [15]. The ratio of power and cooling expense to equipment expenses have increased from approximately 0.1 to 1 in 2000 to 1 to 1 in 2007 [10]. With the likely increase in the number of data centers and servers and the advent of a carbon cap-and-trade scheme, the cost of energy for data center power and cooling will increase continuously [16].

V) **Restrictions on Energy Supply and Access:** Companies such as Google, Microsoft, and Yahoo with the need for large data centers may not be able to find power at any price in major American cities [17]. Therefore, they have built new data centers in the Pacific Northwest near the Columbia River where they have direct access to low-cost hydroelectric power and this has proved beneficial to them because they do not depend on the overtaxed electrical grid. In states such as, California, Illinois, and New York, the old electrical infrastructure and high costs of power can stall or stop the construction of new data centers and limit the operations of existing centers [18]. In some crowded urban areas utility power feeds are at capacity and electricity is not available for new data centers at any price [19].

*VI)***Low Server Utilization Rates:** Data center efficiency is a major problem in terms of energy use. The server utilization rates average 5-10 per cent for large data centers [20]. Low server utilization means companies are overpaying for energy, maintenance, operations support, while only using a small percentage of computing capacity [21].

VII) **Growing Awareness of I. T's Impact on The Environment:** Carbon emissions are directly proportional to energy usage. In 2007 there were approximately 44 million servers worldwide consuming 0.5% of all electricity. Data centers in the U.S use more than 1% of all electricity [19]. Their collective annual carbon emissions of 80 metric megatons of CO2 are approaching the carbon footprint of the Netherlands and Argentina [20]. Carbon emissions from operations are expected to grow at more than 11% per year to 340 metric megatons by 2020. Additionally, the carbon footprint of manufacturing the IT product is largely unaccounted for by IT organizations [20].

D. Eco Friendly Practices

Below some environment friendly approaches are discussed:

*I)*End User: Most personal desktop computers run even when they aren't being used, wasting enormous amount of electricity. Users should not leave them on unnecessarily. Computers generate heat and require cooling, which adds to the total power consumption and cost for the enterprise. While the savings in energy costs per PC may not seem like much, the collective savings for hundreds of computers in an enterprise is considerably high [2]. If proper eco-friendly measures are followed an enterprise may save lot of money and consequently have an increased profit margin. Such an enterprise will have a competitive edge as compared to its competitors.

PC energy consumption can be reduced by adopting several excellent measures as given below [2]:

a. Enabling power management features: Without sacrificing performance, computers can be programmed to automatically power down to an energy-saving state when idle. The US Environmental Protection Agency (EPA) estimated that providing computers with a sleep mode reduces their energy use by 60–70 percent. Because PCs are widely used across any given organization, it is very difficult for the IT staff of any organization to manage their organization's PC power consumption prudently. In this case, a pragmatic approach is to use software such as Surveyor from Verdie [22] that offers network-level control over PCs and monitors. The software places the PC into a lower-power consumption mode, such as shutdown, hibernation, or standby, and monitors into a sleep mode when they are idle. Besides, it also measures and reports how much power each PC and monitor consumes. Network managers can remotely awake the PCs for software upgrades, maintenance, or backup.

b.Using thin client computer: Users can choose to deploy thin- client computers which draw about a fifth of the power of a desktop PC.

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c. Using screensavers: A blank screensaver conserves more power than a screensaver that displays moving images, which continually interacts with the CPU. But even that reduces the monitor's energy expenditure by only a small percentage.

The end user may also follow the following tips for reducing energy consumption [3]: a. Printing: Printing should be done prudently and only those pages should be printed that are absolutely indispensable. Apart from electricity this will save lot of paper and consequently lower cutting down of trees.

b. Refilling: Refilling of ink cartridges and laser toners are cheaper and does not add to landfill. Hence should be carried out.

II) Switching off: I.T hardware devices should be turned off when not in use. Old Computer: Old unwanted computers and monitors shouldn't be thrown away in rubbish bins, as they will then end up in landfills causing serious environmental problems. Instead, they should be refurbished and reused or recycled in environmentally sound ways [2]. Otherwise this will result in irreparable damage to the environment.

Below is a brief outline of the methods that can be followed to achieve the goal [2]:

a.Reuse: An old computer should continue to be used if it meets the user requirements. Otherwise, it can be given to someone who needs it or the functional components may be used from a retired product.

By using the hardware for a longer period of time, the total environmental footprint caused by computer manufacturing and disposal will be reduced greatly.

b. Refurbish: Old computers and servers can be refurbished to meet new requirements. An old computer and other IT hardware can be made almost new again by reconditioning and replacing their parts. Rather than buying a new computer, refurbished IT hardware can be bought from the market. Nowadays, more enterprises are open to purchasing refurbished goods, and the market for refurbished IT equipment is growing.

From the green angle, reusing is a better long-term way of managing resources. Financially speaking, it is more sensible as outward cash flow and capital expenditures are reduced. If these options are unsuitable, the outdated equipment's can be donated to charities or schools or computers can be traded. Charities refurbish old computers and give them to those in need.

c. **Recycle:** When computers cannot be reused, even after considering the prospects of refurbishing, they must be disposed properly in environmentally friendly ways. Vast majority of unwanted computers and electronic goods end up in landfills. Electronic waste or e-waste—is one of the fastest-growing waste types, and the problem of e-waste is a global threat. Analysts predict that two-thirds of the estimated 870 million PCs made worldwide in the next five years will end up in landfills. The United Nations Environment Program estimates that 20 to 50 million tons of e-waste are generated worldwide each year, and this is increasing at an alarming rate. Apart from containing toxic materials like lead,

chromium, cadmium, and mercury, computer components contain many other harmful materials. If computers are buried in landfills, harmful chemicals from them may leak into waterways and the environment. If burned, they release toxic gases into the air we breathe, so if e-waste is not discarded properly, it will be harmful to the environment and people. On the other hand, e-waste can be a valuable source for secondary raw materials. Old electronic systems should be recycled by taking component material and reprocessing it into the same material or breaking it down into constituent materials for reuse.

*III)***Data Center:** The continued popularity and consequent rise of Internet and Web applications is driving the rapid growth of data centers. Enterprises are installing more servers or expanding their capacity to address to the ever-increasing demand of electronic data. The number of server computers in data centers has increased six-fold to 30 million in

the last decade, and each server draws far more electricity than earlier models. Combined electricity uses for servers doubled between 2000 and 2005, most of which came from businesses installing large numbers of new servers. The operational cost of data centers continues to increase steadily with ever increasing energy prices worldwide. Besides the cost, availability of electrical power is becoming a critical issue for many companies whose data centers have expanded steadily. Constraints like social, financial, and practical is forcing businesses and IT departments to reduce energy consumption by data centers. Data center efficiency can be improved by using new energy-efficient equipment, improving airflow management to reduce cooling requirements, investing in energy management software, and adopting environmentally friendly designs for data centers and adopting new measures to curb data centers' energy consumption [2]. So proper management of data centers is the need of the hour.

Three broad measures are outlined below to greening data centers [2]:

a.**Energy Conservation:** I.T industry is investing lot of time and money to devise new and effective ways to conserve energy. Companies like IBM, Hewlett Packard, Spray Cool, and Coligny are working on technologies such as liquid cooling, Nano fluid- cooling systems, and in-server, in-rack, and in-row cooling. Other novel ways of making a data center more environmentally friendly include using new high-density servers, using hydrogen fuel cells as alternative green power sources, and applying virtualization technologies that reduce the total power consumption of servers and lower the heat generated.

b. **Eco-friendly design:** Eco-friendly data center designs use a synthetic white rubber roof, paint, and carpet that contain a low volatile organic compound (VOC), countertops made of recycled products, and energy-efficient mechanical and electrical systems at optimal efficiency. Eco-designs make use of both natural light as well as green power, which is basically electricity generated from solar or wind energy, to run the data center. Enterprises that adopt eco-friendly designs can get tax incentives and also gain a competitive advantage, because more and more customers want to work with eco-friendly firms. While building a new data center provides complete design control, IT professionals can take proactive measures like using energy-efficient windows, skylights, and sky tubes, and changing the paint and carpet to a low-VOC variety to reduce heat, add light, and discard materials that contain toxic chemicals in existing data centers. Many American enterprises are adopting the Leadership in Energy and Environmental Design (LEED) standards maintained by the US Green Building Council [23] for building new data centers. LEED promotes a "whole building approach" to sustainability, focusing on five key areas: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality.

E. **Virtualization:** Virtualization is a major strategy to reduce data center power consumption. In virtualization, one physical server hosts multiple virtual servers. Virtualization enables data centers to strengthen their physical server infrastructure by hosting multiple virtual servers on a smaller number of more powerful servers, using less electricity and simplifying the data center. Besides getting much better hardware usage, virtualization reduces data center floor space, makes better use of computing power, and greatly reduces the data center's energy demands. Many enterprises are using virtualization to curtail the huge energy consumption of data centers. In order to tackle the issue of data centers' huge power consumption, leading IT enterprises formed a non

profit group called the Green Grid [24] in February 2007. This group has the responsibility to define and propagate the best energy-efficient practices in data center operation, construction, and design, and drive new user-centric metrics and technology standards. Green Computer Design

Green computer design aims to reduce the environmental impact of computers by adopting new technologies and using new techniques and materials while balancing environmental compatibility with economic viability and performance. Green design is fast becoming a necessary business practice. Many computer manufacturers are successfully in the process of making green PCs using nontoxic materials that consume less and less of electrical power and can be easily reassembled. These new computers are highly upgradable thus their useful lifetime is extended. Dell, Apple, and other computer vendors have already announced their environmental strategy designed to make their computers green for the long term. Dell aims its new Zero Carbon Initiative at maximizing the energy efficiency of Dell products, and over time plans to offset its carbon impact.

As a major aspect of this initiative, its suppliers have to publicly report their greenhouse gas emissions. Apple is also committed and has said it will reduce or eliminate toxic chemicals present in its new products and more aggressively recycle its old products. Companies have launched new tools, standards, and product registration to help customers in assessing the environmental attributes of PCs, notebooks, servers, and other hardware [2].

*F.***Green I.T Standards and Regulations**

Green I.T standards and regulations, Epeat [25], the Energy Star 4.0 standard, and the RoHS directive [26] provide a guideline in designing green computers and IT peripherals and also classify them based on their environmental attributes. Below is given a brief overview of the various standards and regulations.

*I)***Epeat:** This is an evaluation tool that allows the selection of electronic products based on environmental performance. Launched by the Green Electronics Council [27], the Electronic Product Environmental Assessment Tool (Epeat) assist buyers to evaluate, compare and select desktop computers, notebooks and monitors based on their environmental impact. It also helps manufacturers of electronic products to promote their products as environmentally sound. Epeat evaluates electronic products based on 23 required criteria and 28 optional criteria which are further regrouped into 8 performance categories such as reducing and eliminating environmentally sensitive materials, selecting materials, designing for the product's end of life (such as recycling), product longevity, energy conservation, end-of-life management, corporate performance, and packaging. The registered products are identified as bronze, silver or gold by Epeat. The bronze products meet all 23 required criteria. The silver products meet in addition at least 14 optional criteria. The gold products should meet the 23 required criteria and at least 21 optional criteria additionally. Manufacturers may wish to choose to fulfil the optional criteria to boost their Epeat score and achieve a higher level of product categorization. All Epeat registered products have lower level of hazardous materials like cadmium, lead and mercury. These products are more energy efficient and easier to upgrade and recycle. Epeat recognizes several desktop computers, laptops and monitors from some of the leading

manufacturers as green products. Some computer contracts issued by major government agencies in the US as well as some private enterprises already refer Epeat [2]. *II)* **Energy Star 4.0 Standard:** The new Energy Star 4.0 standard regulates energy performance of external and internal power supplies and gives power consumption specifications for idle, sleep, and standby modes for a number of different devices including PCs, desktops, and gaming consoles. Quite naturally, computers meeting the new requirements will save energy in all modes of operation. Regulations for computers in idle mode are new, as previous standards addressed only sleep and standby modes. The new specifications require OEMs to educate users about power management [2].

III) **RoHS Directive:** The Restriction of Hazardous Substances in Electrical and Electronic Equipment Directive [26] aims to restrict the use of certain hazardous substances within permissible limits. It also bans selling new electrical and electronic equipment on the European Union market if it contains more than the agreed-upon levels of lead, cadmium, mercury, hexavalent chromium or flame retardants [2].

IV) **W.E.E.E Law:** The European Waste Electrical and Electronic Equipment Directive became law in 2003. According to this law the equipment manufacturers has the responsibility for electrical and electronic waste. Producers must take back the equipment free of charge. The intention of the directive is to decrease waste from electrical and electronic equipment and to provide incentives for designing equipment that improves environmental performance throughout the lifecycle

[6]. Producers were required to join a compliance scheme [28] and register in every EU country. Violations are actionable and prosecutable [29].

G. Industry Associations

Below is given a brief outline of some of the industry associations related to green computing [6]:

I) **Green Grid**: The Green Grid [24] is a voluntary international non-profit organization, the main purpose of which is to develop standards to measure data center efficiency including both the facilities and the equipment inside. Member companies share information about processes and technologies that can help data centers improve performance against those metrics. Board members include Intel, IBM, Microsoft, AMD, HP, Dell, EMC, APC, and Sun.

*II)***The Climate Savers Computing Initiative:** Climate Savers Computing Initiative member companies commit to purchasing energy-efficient desktops and servers, and to broadly deploying power management strategies [30]. By openly declaring their support for this effort, companies express their commitment to the "greening" of IT and join other industry-leading companies and organizations in corporate social responsibility and sustainable IT. Board members are CSC, Dell, Google, HP, Intel, Lenovo, Microsoft, and the World Wildlife Fund.

*III)***The Uptime Institute:** The Uptime Institute Inc. provides educational and consulting services for organizations interested in maximizing data center uptime and sustainable IT. The Institute has pioneered industry standards which rate data center availability [31]. The Uptime Network has 100 mostly Fortune 100 sized members. The Institute promotes learning among its members and provides conferences, site tours, benchmarking, best practices, and abnormal incident collection and analysis. Apart from these, it also certifies data center tier levels and site resiliency.

III. CONCLUSION

It can be observed that green computing is the need of the hour to protect the environment. As more and more time passes the need of computers as a dependable machine increases and so does its use. So, computer penetration is increasing globally at an amazing rate. This makes it all the more necessary to maintain green computing procedures throughout the life cycle of a computer from manufacturing through day-to-day operation till the end of its operating stage. In this regard according to David Wang, the data center architecture of Teradata," Every step consumes energy and buying a new, more efficient

computer may not always be the right answer" [32]. Thus, it can be safely concluded that in order to have a healthy and clean environment all stake holders must work collaboratively for a healthier and greener environment for our future generations.

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