International Journal of Advance Research in Science and Engineering
Volume No.06, Special Issue No.(01), Nov 2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

Sustainable Green Computing: Objectives and Approaches

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ABSTRACT

In this research article, we present a brief overview of Green Computing. Green computing aims to reduce the use of hazardous materials, maximize energy efficiency during the product's lifetime, and promote the recyclability or biodegradability of defunct products and factory waste. In past few years, computer and IT industry have realized the importance of going green, both in terms of environmental issues and minimizing costs which has led to remarkable drift in strategies and policies of IT industry. The motivation behind this change comes from the ever increasing business computing demand, ever growing cost of energy, rising awareness of global warming issues. This research article presses upon Environmental Considerations which focuses on need of green computing in general with respect to electronic devices in use and when they are being disposed off giving birth to e-waste and pollution, areas where green computing is highly demanded with respect to cost and energy savings and Initiatives by governments and corporate sectors in this direction.

Keywords: *Green Computing, e-waste, internet of things, data centers.*

I. INTRODUCTION TO GREEN COMPUTING

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

- 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 recycling unwanted computers and other electronic equipment.
- Green Design: Designing energy efficient and environmentally sound components, computers, servers and cooling equipments.

Green Manufacturing: Manufacturing electronic components, computers and other associated sub systems with minimal impact or no impact on the environment. [1] [2]. A green computer or green IT system is one where the entire process from design, manufacture, use, and disposal involves as little environmental impact as possible. In other words, a green initiative is taken in consideration of all facets of a computer's life, from design to disposal. One of the first manifestations of the green computing movement was the launch of the Energy Star program way back in 1992. Energy Star served as a kind of voluntary label awarded to computing products that succeeded in minimizing use of energy while maximizing efficiency. Energy Star applied to products like computer monitors, television sets and temperature control devices like refrigerators, air conditioners, and similar items.

One of the first results of green computing is the sleep or hibernate mode that places computers to power down when not in use and, therefore, save on energy impact.

II. WHY GREEN COMPUTING

The first thing that hits our mind is because it is the need of the hour. Global warming which has been the major disease since it came into light, poses threats for the future. We are in an era where needs and demands are growing by second of the clock. Resources are limited and they should be managed in such a way that our future has some silver linings to it. [3]. This paper has been divided into three sections (1) Environmental Considerations which focuses on need of green computing in general with respect to electronic devices in use and when they are being disposed off giving birth to e-waste and pollution. Section (2) focuses on areas where green computing is highly demanded with respect to cost and energy savings and (3) Initiatives by governments and corporate sectors in this direction.

2.1 Environmental considerations

Many of the technologies we use every day consume a lot more resources and power than they need to, and using and manufacturing them can create a mess. Astonishing technological advancements make life more entertaining and improve the way we work and live. However, each advancement contributes to our environmental threat as we scrap the old and adopt the new.

There are numerous amount of electronic devices for day to day use let's consider a one which is used by almost everyone (A Computer). CPU uses 120 Watts CRT uses 150 Watts 8 hours of usage, 5 days a week = 562 KWatts if the computer is left on all the time without proper power saver modes, this can lead to 1,600 KWatts for a large institution, say a university of 40,000 students and faculty, the power bill for just computers can come to $2 million / year.

Energy use comes from electrical current to run the CPU, motherboard, memory running the fan and spinning the disk(s) monitor. (CRTs consume more power than any other computer component). Printers computer energy is often wasteful leaving the computer on when not in use. (CPU and fan consume power, screen savers consume power) printing is often wasteful how many of you print out your emails or meeting agendas printing

out partial drafts for a "paperless" society, we tend to use *more* paper today than before. Computer-prevalence pollution manufacturing techniques packaging disposal of computers and components toxicity as we will see, there are toxic chemicals used in the manufacturing of computers and components which can enter the food chain and water. Chemical Elements Found in Computers and Components.

- Elements in bulk: lead, tin, copper, silicon, carbon, iron and aluminum.
- Elements in small amounts: cadmium and mercury
- Elements in trace amounts: germanium, gallium, barium, nickel, tantalum, indium, vanadium, terbium, beryllium, gold, europium, titanium, ruthenium, cobalt, palladium, manganese, silver, antimony, bismuth, selenium, niobium, yttrium, rhodium, platinum, arsenic, lithium, boron, americium.

Devices containing these elements almost all electronics contain lead & tin (as solder) and copper (as wire & PCB tracks), though the use of lead-free solder is now spreading rapidly lead: solder, CRT monitors (Lead in glass), Lead-acid battery. Another problem which is faced with respect to environment and management is disposal of the e-waste.

Fig 1: E-Waste

Disposal of the electronic devices constituted 20-50 million tons per year (about 5% of the total waste of the planet). Europe has outlawed using landfills for computer components the US and Europe export a lot of e-waste to Asian landfills (especially China even though China has outlawed the importing of e-waste) in addition, incineration of computer components leads to air pollution and airborne toxins. Steps towards solution listed below

Reuse: donate your computer components to people who may not have or have lesser quality computers this however leads to the older computers being dumped but there is probably no way around this as eventually the older computers would be discarded anyway

Refurbish: rather than discarding your computer when the next generation is released, just get a new CPU and memory chips – upgrade rather than replace while you will still be discarded some components, you will retain most of the computer system (e.g., monitor, the system unit housing, cables)

Recycling: If companies can recycle the plastics and other components, this can greatly reduce waste and toxins

Government regulatory authorities also actively work to promote green computing concepts by introducing several voluntary programs and regulations for their enforcement.

Average computer users can employ the following general tactics to make their computing usage greener:

- Use the hibernate or sleep mode when away from a computer for extended periods
- Use flat-screen or LCD monitors, instead of conventional cathode ray tube (CRT) monitors
- Buy energy efficient notebook computers, instead of desktop computers
- Activate the power management features for controlling energy consumption
- Make proper arrangements for safe electronic waste disposal
- Turn off computers at the end of each day
- Refill printer cartridges, rather than buying new ones
- Instead of purchasing a new computer, try refurbishing an existing device

1.2 Industry understands responsibility

Companies which manufacture electronic products also work for solutions for environmental preservations. There are many global participants who consider the problems as alarming and work towards obtaining solutions. Many companies have taken initiatives. Brief detail is as below.

Nokia, Dell, Sony, Ericsson, Motorola but top of the list is acquired by VIA Technologies. VIA Technologies, a Taiwanese company that manufactures motherboard chipsets, CPUs, and other computer hardware, introduced its initiative for "green computing" in 2001. With this green vision, the company has been focusing on power efficiency throughout the design and manufacturing process of its products. Its environmentally friendly products are manufactured using a range of clean-computing strategies, and the company is striving to educate markets on the benefits of green computing for the sake of the environment, as well as productivity and overall user experience. Amid the international race toward alternative-energy sources, VIA is setting its eyes on Solar Computing, Lead-Free and Restriction of Hazardous Substances Directive (RoHS) computing, Energy-efficient computing VIA's initiative is a significant part of its green-computing projects. [4].

Numerous efforts have been put into by many companies in this respect and have been able to obtain quality results [5] [6] for more detailed information [7].

1.3 Areas of focus where green computing is highly demanded

1.3.1 Green Servers and Data centers

In a world where business is transacted 24/7 across every possible channel available, companies need to collect, store, track and analyze enormous volumes of data—everything from click stream data and event logs to mobile call records and more. But this all comes with a cost to both businesses and the environment. Data warehouses and the sprawling data centers that house them use up a huge amount of power, both to run legions of servers and to cool them. Sixty three billion kilowatt-hours of electricity, at an estimated cost of $4.5B annually. The IT industry has begun to address energy consumption in the data center through a variety of approaches including the use of more efficient cooling systems, virtualization, blade servers and storage area networks (SANs). But a

fundamental challenge remains. As data volumes explode, traditional, appliance-centric data warehousing approaches can only continue to throw more hardware at the problem. This can quickly negate any green gains seen through better cooling or more tightly packed servers. To minimize their hardware footprint, organizations also need to shrink their "data footprint" by addressing how much server space and resources their information analysis requires in the first place [8].

Fig 2: Data Center near Arctic Circle

For many of the technology giants, one of the biggest costs they face is in maintaining data centers. For companies like Google, Facebook organizing the world's information comes at the high cost of running some of the largest, most sophisticated data centers in the world. Energy use is one of their biggest operational expenses for many of these companies. This creates an alignment of environmental and business interests for companies like Google and Facebook, who are finding innovative ways to reduce their energy consumption.

Google is incredibly active in creating efficient data centers, maintaining tight control of all their operation. In fact, this is arguably one of Google's core business areas. They design and build their own facilities and recycle all of the equipment that leaves their data centers. The battle between the tech giants, Google, Apple and Amazon, is on some level a battle over data centers. All of these companies are striving to create efficient data centers that will house the world's information while minimizing financial, and environmental impact. Both Google and Apple have opened data centers that are either wholly or in part fueled by alternative energy. Google has created an entirely wind powered data center, and Apple has recently filed for patents for proprietary wind turbine technology. This shows how central energy efficiency is to the goals of these tech firms. Efforts are continuously being made to reduce the carbon footprint left by the data center industry via various methods and mediums.

A recent survey report shows that this industry uses almost 3-percent of the world’s energy. Actually, several big data centers may consume such vast quantities of power – adequate to light up a whole city! In this kind of situations, the management representatives of data center firms are liable to manage its operations as efficiently as possible in the most eco-friendly way possible. Data center companies may opt to trim down the idle and unused servers. Alternatively, they may also embrace measures that reduce energy consumption such as exploiting renewable energy like:

Geothermal Energy: The data center providers can make use of geothermal energy, which is available naturally in plenty in Iceland and mid-west nations.

Solar Energy: Solar panel installation is one of the very common and energy efficient ways to meet the industry's power requirements.

Wind Energy: As of now, very few firms use wind turbines as a source of energy, but in the very short future, the data center industry would surely be seen adopting this source for its energy requirements.

Recycling Heat: Several firms are recycling heat released from the racks' back for generating energy. [9]

2.3.2.Internet of Things goes green

Internet of Things (IoT) is innovation in the field of Communication where a number of intelligent devices are involved sharing information and making collaborative decision. IOT is going to be a market-changing force for a wide variety of real-time monitoring applications, such as E-healthcare, homes automation system, environmental monitoring and industrial automation as it is supporting to a large number of characteristics and achieving better cost efficiency.[10]

Fig:3 Internet of things

It is expected that the Internet of things will become a reality over the next 20 years; with omnipresent smart devices wirelessly communicating over hybrid and ad-hoc networks of devices, sensors and actuators working in synergy to improve the quality of our lives and in synergy to improve the quality of our lives and consistently reducing the ecological impact of mankind on the planet. Energy issues such as energy harvesting and low-power chipsets are central to the development of the IoT. There is a need to research and develop solutions in this area, having as objective a level of entropy as close as possible to zero. The development of new and more efficient and compact energy storage like batteries, fuel cells, and printed/polymer batteries etc; as well as new energy generation devices coupling energy transmission methods or energy harvesting using energy conversion will be the or energy harvesting using energy conversion will be the key factors for implementing autonomous wireless smart systems[11]. Also throw light on ongoing and intensified research in this area.

2.3.3.Green Cloud Computing

According to market research conducted by Pike Research, the wide-spread adoption of cloud computing could lead to a potential 38% reduction in worldwide data center energy expenditures by 2020. The savings would be primarily achieved by consolidating data centers and maximizing power usage efficiency (PUE), improving recycling efforts, lowering carbon and gas emissions and minimizing water usage in cooling the remaining centers. Because so much of a data center's energy expenditures support data storage, the Storage Networking Industry Association (SNIA) has promoted new technologies and architectures to help save energy. Advances in SAS drive technologies, automated data duplication, storage virtualization and storage convergence reduce the amount of physical storage a data center requires, which helps decrease its carbon footprint and lower operating expenditures (OPEX) and capital expenditures (CAPEX). Because the color green is also associated with paper money, the label green cloud is sometimes used to describe the cost-efficiency of a cloud computing initiative [12]. Cloud computing business potential and contribution to already aggravating carbon emission from ICT, has lead to a series of discussion whether Cloud computing is really green. It is forecasted that the environmental footprint from data centers will triple between 2002 and 2020, which is currently 7.8 billion tons of CO2 per year. There are reports on Green IT analysis of Clouds and datacenters that show that Cloud computing is "Green", while others show that it will lead to alarming increase in Carbon emission. Garg and Bhuva also presented solution oriented measures to meet the challenges in green cloud computing. [13].

It is pertinent to mention here that green cloud computing comes with enormous benefits. Vivek, Bala [14] throw light on various benefits in GCC some of them are Reduced Cost, Automatic Updates, Remote Access Disaster, Relief Self-service provisioning, Scalability, Reliability and fault-tolerance, Ease of Use Skills, Proficiency, Response Time, Increased Storage Mobility.

III. INITIATIVES BY GOVERNMENTS AND CORPORATE SECTOR

Many governments worldwide have initiated energy-management programs, such as Energy Star, an international standard for energy-efficient electronic equipment that was created by the United States Environmental Protection Agency in 1992 and has now been adopted by several other countries. Worldwide, standby power is estimated to account for as much as 1 percent of global greenhouse emissions. All most every country has adopted standards to safeguard their interests as far as environment is concerned. Some initiatives by governments are highlighted below.

In 1998, the China National Development and Reform Commission (NDRC) founded the China Energy Conservation Program (CECP), a nonprofit organization in charge of the administration, management, and implementation of the certification for energy- conserving, water-saving, and environmentally friendly products. [15]

In May 2006 Ministry of power Govt. of India formally launched the standards and labeling scheme for adoption of section 14 of energy conservation act 2001 (52) of 2001, since then bureau of **energy efficiency has been promoting and facilitating its adoption**.[16]

U.S. federal government increases commitment to EPEAT green computing. In another step to ensure that all Federal agencies purchase and use the 'greenest' computers available, the U.S. federal government has integrated a requirement for use of EPEAT (the Electronic Product Environmental Assessment Tool) into the Federal Acquisition Regulations (FAR) -- the 'bible' of the federal purchasing sector. A Presidential Executive Order in January 2007 called on federal agencies to ensure that 95 percent or more of all computers they purchase are qualified under the EPEAT green computer purchasing standard; the proposal to include this requirement in the FAR will make it standard practice for all federal government purchasers. [17]

3.1 Going Green at Work

Organizations all over the world are beginning to understand their corporate social responsibility toward the environment. Most companies now believe in conserving energy and power and using environmentally friendly products that help in reducing their carbon footprint. In fact, in many organizations, the need for green computing is put at the top of the agenda. Nowadays, it is imperative for all sized organizations to implement aspects of green computing in their daily workings.

Organizations must follow these simple steps for creating the green computing awareness in their workplaces.

- Announcing green intentions to all employees.
- Setting up a committee to form a green IT plan.
- Centralization of all desktops.
- Using efficient computer applications.
- Power management tactics.
- Business performance enhancement.

The most common actions organizations have undertaken are:

Virtualization: Virtualization is the consolidation of servers and systems to reduce power consumption and energy utilization. It leads to usage of more than one system on a single piece of physical hardware. This allows for minimum power consumption and maximum cooling.

Power Saving: Industry standards like ACPI design and manufacture computer components in such a way that they result in power controlling and saving.

Telecommuting: Employees working from home reduce the fuel emission created during commuting by vehicles. Moreover, there is reduction in overhead costs on utilities, etc. All of these initiatives result in increased power and energy savings.

VoIP: VoIP stands for Voice over Internet Protocol and results in less telephone wiring and lower costs.[18]

In May 2007, IBM unveiled its *Project Big Green*, dedicated to increasing energy efficiency across the company's branches around the world. Experts say that businesses will continue to invest in clean computing, not only because of future regulations, policies, and social demands to reduce their carbon footprint, but also due to the significant long-term savings it can make. Several companies are already headfirst into the green-computing business. Located in the Silicon Valley and founded in 2006, Zonbu is the first company to introduce

a completely environmentally responsible computer – Their "Zonbox" computer is a carbon-emission neutral computer, thanks to a low-power design and regulatory-grade carbon offsets. The device, which complies both to Energy Star standards and the Restriction of Hazardous Substances Directive (RoHS), consumes only 15W, compared to the 175W consumed by a typical desktop PC. Zonbu also provides a free take-back program to minimize environmental e-waste.

Another American company, Everex, has released the Impact GC3502, a green PC that uses 20W of power, owing to a 1.5GHz VIA C7-D processor.[15]

IV. CONCLUSION

The intension behind writing this article is to support the idea of environment protection for upcoming generations and to highlight the fact that the smart world will not exist without optimal usage of resources and energy. New computing innovations and applications need to fulfill the green computing requirements for the sustainable development of Information and communication technology (ICT). As discussed in section A of this paper green computing is our responsibility. Every ICT user has to understand and take preventive measure to use devices and services very efficiently and contribute minimum to e-waste. In addition, regulatory agencies are making positive moves to stem a rising tide of e-waste. Electronics manufacturers are doing their part because of governmental regulations, and because it's good business to do so. RoHS (Restriction of Hazardous Substances), in particular, is a bright spot because of its global adoption. Meanwhile, technology continues to yield solutions with greater energy and material efficiency. Based on the growth of the industry, the power needs are increasing and thus there is a need to monitor the power usage. As the power needs increase, more earth-friendly measures can to be taken to help the environment. Also, the management and administrators need to discuss the increasing needs of the data centers.

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