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A Review on Green Computing for Eco-friendly and Sustainable IT

Khalid Raza[1] V. K. Patle[2] Sandeep Arya[3,*]

[1]*Department of Computer Science, Jamia Millia Islamia (Central University), New Delhi, India.*
[2]*School of Studies in Computer Science and IT, Pt. Ravishankar Shukla University, Raipur, India.*
[3]*Department of Physics and Electronics, University of Jammu, Jammu, India.*

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A Review on Green Computing for Eco-friendly and Sustainable IT

Khalid Raza[1] V. K. Patle[2] Sandeep Arya[3,*]

[1]*Department of Computer Science, Jamia Millia Islamia (Central University), New Delhi, India.*
[2]*School of Studies in Computer Science and IT, Pt. Ravishankar Shukla University, Raipur, India.*
[3]*Department of Physics and Electronics, University of Jammu, Jammu, India.*

{ [1]kraza@jmi.ac.in, [2]patlevinod@gmail.com, [3,*]snp09arya@gmail.com }

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The information and communication technology (ICT) has changed the way we live, work, learn and play but at the same time, it is affecting our environment in several ways. It has created many opportunities for employment round the globe as the computer literacy becomes a prerequisite condition for sustenance in almost every public/private sectors. The computer's ability to store, retrieve and manipulate large amounts of data rapidly and cheaply has led to its wide spread use in managing many clerical, accounting and service documentation functions in organizations. But, at each stage of computer's life, from its production, throughout its use, and into its disposal, it exhibits some kind of environmental problems. Several scientists and authors have quoted their reports on ICT and its impact on the environment. Still, the debate on the effectiveness of green computing for eco-friendly and sustainable IT remains an open issue. In this paper, we report the awareness towards green computing and present the summary of key areas where IT organizations can achieve savings in terms of energy and cost. In addition, we discuss a formal approach of green computing along with its standardization and compliances and some of its challenges.

Keywords: Green computing, eco-friendly, green design, green manufacturing, green use, green disposal.

1. INTRODUCTION

The immense growth of industrialization around the globe sorely affects the environment. The information and communication technology (ICT) also affects our environment in several different ways. Manufacturing computers and its various electronic and mechanical components consumes electricity, raw materials, chemicals, water, and generates hazardous waste. All these resources directly or indirectly increase the carbon dioxide (CO_2) emissions. Now-a-days, the world is thinking of preventing our planet 'Earth' from global warming and climate change [1]. Among the gases present in the atmosphere, CO_2 is the main greenhouse gas emitted due to human activities and is one of the main causes of global warming. Although it is naturally present in the atmosphere as a part of the Earth's carbon cycle but human activities are altering the carbon cycle by adding more CO_2 to the atmosphere and by removing natural sinks of CO_2. CO_2 emits from several natural sources but human-related emissions are responsible for its increase due to industrial revolution. It is pertinent to mention that each personal computer (PC) in use generates about a ton of carbon dioxide every year. The imbalance in the composition of air due to increase in CO_2 may cause global warming. The

global warming may lead to disastrous consequences such as, increase in sea level due to melting of ice caps which will make coastal plain, uninhabitable and change in weather systems. As a result, it may cause more droughts, floods, stronger storms and extremes of weather that affects the agricultural productivity, depletion of ozone layer, spread of diseases due to increase in atmospheric temperatures, and major change in ecosystem, and so on [2].

Today, from mobile phones and micro-computers to the Internet, ICT has consistently delivered innovative products and services and thus becomes an integral part of our everyday life. But on the other hand, it is immensely contributing to environmental problems such as global warming and climate change. ICT is participating roughly 3% of global electricity usages and carbon dioxide emission [5], and if same trends continues, it is predicted to be 6% by 2020 [3]. A recent Internet Data Center (IDC) report estimated the worldwide spending on enterprise power and cooling to be more than $30 billion and likely to even surpass spending on new server hardware [4][6]. Keeping in view all these facts, researchers are now paying serious attention toward green computing as an initiative for cost-saving, eco-friendly and sustainable IT. Increased awareness about global warming and climate change will force the industries around the globe to review their environmental credentials [2].

2. GREEN COMPUTING: BENEFITS AND IMPORTANT FACTS

Green computing (also called Green IT or ICT sustainability) can be defined as the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems, such as projectors, monitors, printers, storage devices, and networking and communications systems, efficiently and effectively with minimal or almost no impact on the environment [7]. The goal of green computing is 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. Green computing also attempts to achieve economic feasibility and improved system performance and use, while abiding by our social and ethical responsibilities. It also provides solutions that save energy at various levels of use. These include (i) hardware, (ii) software and (iii) services [2]. The hardware should be energy-efficient PCs, thin-client architectures. In the software and service area, there is significant potential in virtualization, solutions for dynamic capacity management and data-center planning, and storage-system off shoring. The current trends of green computing include energy efficient CPUs and peripherals, power reduction through known energy-conserving approaches, and the proper recycling and disposal of all the components.

The idea of "green computing" started in 1992 when the US Environmental Protection Agency (EPA) launched a voluntary labeling program, known as *Energy Star*, to promote energy efficiency in hardware of all kinds. The Energy Star label has now become a common sight and an important certification. Today, servers, laptops, displays, gaming systems, and many other computing peripherals offerings include Energy Star compliance in their product descriptions [5].

2.1. Benefits of Green Computing

The benefits of green computing are enormous. It is not only from just the consumer, or business, or country's viewpoint, but a global benefit. It helps reduce energy demands, waste, cost and how we use technology which positively effects the environment. In [2], some of the benefits of green computing are described as in table 1.

Table 1 Some of the benefits of green computing

Tangible Benefits	Intangible benefits	Benefits to an organization
Capital improvements	Environmental benefits like pollution controls	Reduce overall energy consumption
Maintenance savings	Economic benefits (Eco-sustainable development)	Reduce data-center footprint
Better and safer lighting	Social benefits	Encourages efficient utilization of natural resources
E-waste reduction	Secured head disbursement issues controlled	Optimize server capacities and performance
Energy saving and efficiency	Increased user efficiency	Reclaiming valuable floor space through virtualization
Space saving	Simple and reliable IT infrastructure	Provide rapid and secure access to required data
Technological advancement	Testing application software on multiple platforms is easy	Increase ease of systems and solutions management
Travel reduction (Video conferencing & collaboration)	Emotional risk minimizing	Recycle end-of-life equipment
Utilize resources more efficiently	Behavioural risk minimizing	Free-up budget components

2.2. Important Facts about Computing

- The use of screen savers does not save energy.
- Leaving a computer running consumes electricity and adds to computing costs.
- It is estimated that a typical desktop computer with a 17-inch flat panel LCD monitor requires about 100 watts—65 watts for the computer and 35 watts for the monitor. If it left on 24x7 for one year, it will consume 874 kilowatt hours of electricity and release around one ton of CO_2 [2].
- Data centers typically account for 25% of total corporate IT budgets and for information-intensive organizations, it can account for over 50% of the total corporate carbon footprint [11].
- Data center power and cooling costs have increased 800% since 1996 [8].
- In the next five years, it is expected that most U.S. data centers will spend as much on energy costs as on hardware, and twice as much as they currently do on server management and administration costs [9] [8].

3. Growth Statistics of Internet Usages

Today Internet is considered a very powerful platform that has changed the way we do business, and the way we communicate. It continues to grow day-by-day. Table 2 shows the amazingly rapid growth of the Internet from 1995 till the present time globally. Table 3 shows statistics of top ten countries of Internet users [10]. Almost one-third of the world population uses Internet.

3.1. Factors Driving the Adoption of Green Computing

Following are some of the trends that are impacting data centers, servers and desktop computers for driving the adoption of green computing practices [12].

- The rapid growth of the Internet and ICT usages
- Increasing cooling requirements for equipments
- Increasing equipment power density
- Increasing energy costs
- Restrictions on energy supply access
- Low server utilization rates
- Growing awareness of IT's impact on the environment.

Table 2 Global Internet user growth (1995-2012)

Year	Number of users (in millions)	% of world population
1995	16	0.4 %
1996	36	0.9 %
1997	70	1.7 %
1998	147	3.6 %
1999	248	4.1 %
2000	361	5.8 %
2001	513	8.6 %
2002	587	9.4 %
2003	719	11.1 %
2004	817	12.7 %
2005	1,018	15.7 %
2006	1,093	16.7 %
2007	1,319	20.0 %
2008	1,574	23.5 %
2009	1,802	26.6 %
2010	1,971	28.8 %
2011	2,267	32.7 %
Mar, 2012	2,280	32.7 %

4. Formal Approach to Green Computing

The first and foremost necessity of the green computing for information and computing technology is to reduce the power consumption, synthesize environmental friendly devices and educate the people towards green computing [7][8]. To design the electronic equipments environmental friendly, we divide our approach into six components as shown in fig. 1.

Table 3 Top 10 countries of Internet users

Country	Population (2011 Est.) (in millions)	Internet Users, 31-Dec-11 (in millions)	Penetration (% Population)	Users % in the country
China	1,337	513	38.4 %	38.37
US	313	245	78.3 %	78.27
India	1,189	121	10.2 %	10.18
Japan	126	101	80.0 %	80.16
Brazil	203	79	39.0 %	38.92
Germany	81	67	82.7 %	82.72
Russia	139	61	44.3 %	43.88
Indonesia	246	55	22.4 %	22.36
UK	63	53	84.1 %	84.13
France	65	50	77.2 %	76.92

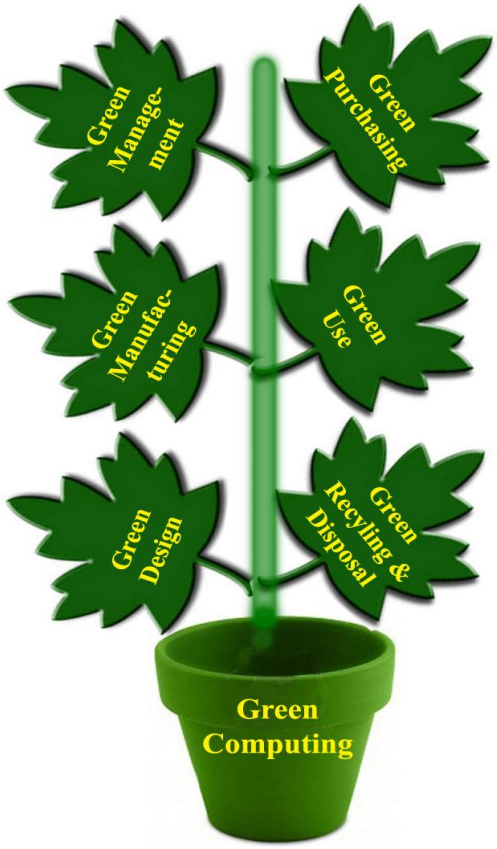

Fig. 1 Formal approaches to green computing

4.1. Green Design

Green design intends to analyze, design and synthesize the environmental friendly products with excellent efficiency. During literature survey, it has been noticed that environmental effects were ignored during the design stage. Perilous wastes were dumped without noticing the environmental issues [13]. Most of the products were inefficient with huge operating costs. In today's era, the challenge of green design is to design and manufacture the products that incorporate environmental considerations analytically and effectively. This requires modifications in these existing techniques [14][15]. Altering the design techniques is difficult due to many conflicting objectives and demand that requires high operating speed and cost effectiveness. Environmental issues have to be introduced in realistic into these new and complicated design processes.

4.1.1. Objectives for green design

The main objective for green designing is to ensure a sustainable future for our society, in regard to both resources and ecological health. It is essential to modify and develop new technologies for future generations. Simultaneously, these technologies should be eco-friendly and may overcome by the environmental problems caused now [16].

Basically, there are three main objectives for green design for a sustainable future [17].

a. Reduce or minimize the use of non-renewable resources
b. Manage renewable resources to ensure sustainability, and
c. Reduce, with the ultimate goal of eliminating, toxic and otherwise harmful emissions to the environment, including emissions contributing to global warming.

4.1.2. Green Design Methods

a. The materials or components used in and out of a manufacturing station should be eco-friendly. There should be no or small residues/wastes and most of the waste materials should be recyclable [18].
b. The designer or manufacturer should compare the green score of alternatives (materials, components or processes, etc.) and choose the one with the minimal environmental impact. This would contribute to products with reduced environmental impacts.

4.2. Green Manufacturing

The process of green manufacturing techniques has already brought into play. Some major industries have already taken massive steps toward a greener prospect by altering their designs to make more efficient processes and increase the reusability and recycling rate of the finished products [19]. They have adopted a number of best practices such as lean manufacturing and green practices as part of their corporate policy. Moreover, they have also gone ahead with hygienic delivery schemes to encourage minimal waste formation, which increases the efficiency of the supply chain and thereby, lowers resource utilization [20].

Extra care is necessary while manufacturing computing and electronics devices and components that include lead-free electronics, halogen-free flame retardants, environmentally-friendly electronics, and the trend towards integrating electronic functions both on and within printed circuit boards (PCBs) [22]. Although green practices within the electronics manufacturing industry may be challenging but its long-term benefits are significant, as it not only reduces the carbon footprints, but also helps them cut costs through lowered energy consumption and improved process control [21]. These advantages with improved energy efficiency may get

recognition by the environment conscious consumers.

4.2.1. Why Green Manufacturing?

The perilous materials included in electrical and electronics equipments can cause major environment problems especially if the waste management is not properly treated. Lead (Pb) is recognized as one of the most significant environmental health threats to the human, especially to pregnant women, infants and children up to six years of age [23]. The lead (Pb) used in electronics accounts less than 2% of the total consumption. Only 40% of the amount of lead in the dumps is from the waste of electrical and electronics equipment. Among 40%, 4% is from lead in PCBs while 36% is due to the use of leaded glass in monitors and television as the CRT on monitors and TV contains kgs of lead. Despite the weight of argument against the decision to ban lead from passive and active components, the electronics industry has started to move forward reducing the use of perilous substances. The first step of environmental friendly implementation is to restrict or eliminate the use of certain perilous substances in electrical and electronics equipment which causes the significant environment problems during the waste management phase. By the timeline, these substances shall not be contained in the electronics equipment.

4.2.2. Virtual Green Manufacturing

The virtual green manufacturing (VGM) is a modern manufacturing model that takes environmental impact and resource consumption into account and its goal is to bring down the negative impact on ecological environment, maximum resource utilization in entire product life cycle such as designing, manufacturing, packaging, and transportation [24]. Virtual green manufacturing is generated with the rapid development of information technology and adjusting to values diversification, is the extension and development of modern manufacturing technology. Essentially, virtual green manufacturing is generating all digital models of actual production through carrying out abstracting, analysis and synthesis to actual manufacturing systems. Based on three-dimensional modeling software, virtual reality modeling language, simulation analysis and calculation can be established by virtual green manufacturing [24]. It integrates and synthesizes manufacturing environment that can be run: including a variety of analysis tools, simulating tools, application tools, control tools, information model, equipment, organization and coordination work methods and so on. The VGM is used to improve each stage from conceptual design of assembly products to dynamic simulation and recycling.

4.2.3. Development of Green Products

During the green product development and manufacturing process, some problems may be hard to forecast, if potential problems of green product designing are not found until product have been actually produced then it will cause larger wasting or extending development cycle of product. VGM can effectively solve above-mentioned problems. It provides designers with the environment of designing and evaluating product. Potential problems of product (performance, cost, manufacturing, assembly and so on), can be found at the earliest possible time with ideal machining process course and erection scheme of products [25].

Microscopic process of materials preparation can be simulated through virtual manufacturing (VM) thereby realizing green optimal design about new material component. Realizing simulation for product packaging and to evaluate product functionality, product design quality can be improved and design defects can be reduced or product performance can be optimized. Also, shortening the manufacturing cycle, reduces production costs [24].

4.2.4. Simulation and Optimization of Virtual Enterprise

Virtual enterprise is a new management model that generated in the background of human into knowledge economy, the goal is timely seizing market opportunities, rapid production of new green products, so that all federate enterprises can profit through green design, green materials, green technology, green production, green packaging and green recycling techniques by minimizing negative effect on environment and maximizing resource efficiency throughout the life cycle of green virtual enterprise. VM system provides virtual enterprise with collaborative support, provides cooperative partner with collaborative work environment, virtual enterprise dynamic composition and support environment [24] [25]. Off-site research and development efforts can be linked by VM system through network and video systems, to carry out off-site development, online discussions. Each link can be simulated from customers ordering, product innovation, design, parts production, unit assembling, sales and after-sales service, providing support for virtual dynamic combination. In many developed countries, virtual enterprises have become a combination of highly developed information technology and enterprise pursuit of innovation.

4.3. Green Management

The main objective of green management is to implement and control the system. For successful green management, the procurement and purchasing of the right material for green manufacturing is one of the most critical point [23][26]. Five components in green management have been proposed as discussed.

4.3.1. Material for Green Manufacturing

An electronic equipment comprises of various electronics components. It can be from few to thousands components [25]. So the green electronics equipment will never be possible if the components are not green.

4.3.2. Process for Green Manufacturing

The green manufacturing process is one of the most significant factors in green realization. For example, the soldering process both wave soldering and reflow that the major substances are solder has been composed of Tin and Lead [27][28]. The manufacturing now is facing the replacing problem of solder by other substances. So this factor is one of major concerns in implementation.

4.3.3. Environment for Green Manufacturing

The environment is one of the factors concerned during implementation [28]. The major problem affects the working people in manufacturing due to improper air flow of manual soldering, wave soldering or even the reflow process.

4.3.4. Packaging for Green Manufacturing

Packaging of material contained the perilous substances such as cadmium in printing ink. The manufacturing should consider this factor in green implementation accordingly [23].

4.3.5. Recycling for Green Manufacturing

The recycling system is the final but most important process before all the waste is out of the manufacturing. The recycling system installation depends upon the investment of the manufacturing. Thus, the obstacle of this factor is the investment cost.

4.4. Green Purchasing

Green purchasing is the most important purchasing method adopted now-a-days. Customers of every category are being encouraged for green purchasing. Each and every IT companies and individuals are moving towards green purchasing. One of the ways is purchasing electronic products having labels such as EPA Energy Star (US), TCO 95 (Sweden), and Blue Angel (Germany) [29]. This is also encouraging for the companies to manufacture greener products that consumes less power, and creates less harm to environment. Different strategies are being followed by different companies in different countries to manufacture their products green.

4.4.1. Purchase Criteria

We should motivate the people/users to consider the electronic and communication gadgets that are manufactured to operate in environmentally sensitive ways, i.e., the gadgets have raw materials for manufacturing that meet a maximum reusable waste targets; use raw materials that are recyclable at the equipments end of use stage; use packaging concepts that are environmentally friendly or recyclable [29]. For example, Energy Star electrical efficiency standard products are environmentally sensitive in daily operations and consume less or recyclable resources throughout its useful life.

4.4.2. Purchasing Policies for Manufacturers and Users

To purchase the computers and other electronic equipments like routers, printers, air-conditioners, etc., the following procurement initiatives could be adopted:

i. Establish standards and benchmarks to define a green purchasing policy for computers. Determine environmental evaluation criteria to compare technologies and components. Utilize reliable third party monitoring and testing organizations independent of suppliers. Use existing computer templates from systems contracting tenders as benchmarked specifications for comparative purposes [29].
ii. Define complete purchasing policy with purpose, scope and procedures. Construct terms and conditions for future tenders and contracts. However the user departments would have to accept these terms and be willing to incorporate eco-labels and other environmentally friendly functionality into their specifications.
iii. Adopt standards issued by ecological standards associations and identify their labeling criteria, i.e., Energy Star, Energy Guide, Green Seal, etc. to incorporate into procurement practices. Communicate procurement information

resources within the companies via purchasing service's website and provide resource links as appropriate. Incorporate training and education of new environmental criteria and processes into existing client training program.

iv. Report/update purchase activity in support of green initiatives, including day-to-day progress to sustainability coordinator for incorporation of awareness program.

4.5. Green Use

Saving of energy leads to reduced pollutants and that means healthy environment. Hence, the user should be aware of green use to reduce the energy consumption of computers and other information systems as well as using them in an environmentally sound and efficient manner [30]. Table 4 shows the power consumed by different components of a computing system [31].

Table 4 Power consumed by different components

Component	Requirement
Processor	80W - 140W
RAM	15W per stick of RAM
Motherboard (w/o CPU or RAM)	50W - 150W
Hard Drive	15W - 30W
Case/CPU Fans	3W (ea.)
DVD/CD	20W - 30W
AGP Video Card	30W - 50W
PCI Express Video	50W - 150W (one power connector)
Average PCI Card	5W - 10W

To save energy and the environment, some guidelines are as follows:

a. By using power option in control panel of operating system

Turn off monitor: This mode allows us to turn off the monitor, if the system is idle for more minutes [30] [32]. By turning off our monitor we can save half the energy that is used by the system. So turn off the monitor when download in progress or when it is in idle for some minutes. We can automate through this option. Turn of monitor, after it is idle for 10 minutes, that's what we can recommend.

Turn off hard disks: This mode allows us to turn off hard disks if it is idle. We can automate this and set the turn off time to 30 minutes or to some other value depending upon your usage.

System standby / sleep: This mode allows us to save a lot of power. It will turn off the monitor, hard drive, sound card, graphics and video cards [30] [33]. The current state of the system will be saved in RAM. If we want to use it again, we can move the mouse or touch the keyboard to make everything turn on. We can recommend this option over hibernate option for both desktops and laptops.

Hibernate: This mode allows us to shut everything down. The difference from sleep/ standby mode is how it is storing our information in the RAM; it will write all the information to the hard drive and shuts everything down. This allows to keep hard disk in standby. But hard disk doesn't use much power. So, we recommend this option for only laptop users if it is running on battery.

b. Eliminate phantom loads

Phantom load is the leakage electricity by electronic appliance while they are switched off. Phantom loads, such as the 3 watts used by the hibernate mode, occur when electrical devices appear to be powered off but continue to consume electricity. Many electrical devices exhibit phantom loads because they do not have a physical switch that disconnects the electrical connection to an electrical socket [30]. For example, most computers exhibit a phantom load of 1-3 watts due to a constant draw by AC/DC adapters or LAN-friendly wake up functionality, among other causes [34]. Wake up on LAN allows a completely shut off computer to be turned on remotely from a machine on its network, an important capability when administering a network. The following equation approximates the cost that a user who has 10 electrical devices, each consuming as little as 3 watts when "off," will incur in one year: 263 kWh (10 devices * 3 W * 24 hours * 365 days * 1 kW / 1000 W year Power).

The solution to the phantom load problem is to pull the plug from the wall when the electrical device is not in use, with a more convenient alternative being the use of a switchable power strip. More sophisticated power strip devices are available that can automatically power off any devices plugged into the strip when a specific device, such as the computer, is powered off [34].

c. Buy the new "smart" power strip

The Smart Strip actually senses how much power our computer peripherals use. When the Smart Strip senses that you've turned your computer off, it automatically shuts off peripherals too, preventing them from drawing an idle current, which is the current drawn even after equipment is

shut off.

d. Algorithm efficiency

The efficiency of software algorithms has an impact on the amount of computer resources required for any given computing function and there are many efficiency trade-offs in writing programs. As computers have become more numerous and the cost of hardware has declined relative to the cost of energy, the energy efficiency and environmental impact of computing systems and programs has received increased attention.

4.6. Green Disposal and Recycle

Green computing disposal provides a flexible and audit-managed solution for the collection and re-processing of end-of-life redundant computing equipment and computer recycling. It is easier to think of to 'go green'. For a positive environmental impact with computer recycling by correctly disposing of unwanted computers and computing equipment with green computing disposal, it is even easier to collect and process the unwanted items at absolutely no cost. With computer recycling we are actively reducing waste, minimizing CO_2 emissions and controlling processing costs [35]. It gives the potential to generate a revenue return. If the equipment is still functional, the best way is to continue to be used by someone else, until such time as it fails or it no longer is in use. Once it is useless, the equipment can be recycled. It is important to ensure that data is erased from equipment before anyone else gets to use it. Many organizations would like to have their old equipment reused or possibly even resold to realize a disposal value, but don't have the time or expertise to organize this.

4.6.1. Recycle the Components

Most parts of electronic equipment can be recycled. Meanwhile, having "green credentials" is becoming an ever increasingly important aspect of the business world [36]. IT leaders can arrange the most appropriate environmentally friendly disposal solution for quantity of equipment, and provide a technology recovery/recycling certificate.

a. Recycle electronic components: Electronics recycling is becoming more common in many urban areas, battery recycling is everywhere (rechargeable batteries are ecologically sounder, but even they wear out after a while), and there are a number of non-profit organizations that will take computer parts and turn them into working computers for others. Companies like Ebay have also developed programs to help electronics find new homes [29]. Other groups will gladly recycle our cell phone or give it to a senior citizen, as even without a contract it can still make emergency calls. If a major appliance doesn't work and someone wants to replace it and try to fix it, offer it to local repair shops, trade schools, or hobbyists to tinker with. Many cities now offer perilous waste recycling days when they will take not only perilous waste, but electronics. During a survey, it came to know that 20 million tons of electronic waste thrown away each year. One ton of scrap from discarded computers contains more gold than can be produced from 17 tons of gold ore [29].

b. e-waste collection: When a device breaks down or becomes obsolete, its components and parts can still be processed by using them as spares, refurbishing and recycling them, donating them or breaking them apart in order to reuse components and parts.

c. Reduce toxic waste: Reducing e-waste is very much important. By practicing green computing, we had to know how to properly dispose the computers and other hardware devices. First check the manufacturer information that they may take back your old product back. In now a day's many concerns take the old gadgets from you to get them recycled [37]. Depending on where we live, we can take the old parts of computers to nearby retailers, electronics repair shop they can dispose products easily to recycler.

5. Environmentally Sound Practices for Computing

Understanding how power consumption impacts the "greenness" of any technology is an essential step toward reducing this consumption and educating users. This section describes some of the environmentally sound practices for computing [30].

Reducing energy consumed by computers: A typical computer consumes 100 watts of energy. We can reduce energy consumption by changing the way we use it. Many times computers remain on even when they are not being used, because users needlessly leave them on, wasting electricity. In addition, computers produce heat and it need additional cooling and adds burden to the total power consumption and cost [38].

Greening data centers: Due to rapid growth of Internet and World Wide Web (WWW), enterprises are installing more and more servers. Data center energy and emissions costs are major concern in green computing analysis because more than half of all IT-related electrical costs are generated there. Data centers typically account for 25% of total

corporate IT budgets and their costs are expected to increase as the number of servers rise and the cost of electricity increases faster than revenues. One study shows that the cost of running data centers is increasing 20% per annum on average [39]. In 2005, the power and cooling cost for servers worldwide was US$30 billion, and that cost is forecasted to top $40 billion by next year [5]. The study by Gartner Group [40] found that data centers, with their associated servers, air conditioners, fans, uninterruptible power supply (UPS), and so on, use 100 times of energy per square foot of an office building. We can get better data center efficiency by using sophisticated energy-efficient equipment, improving airflow management to reduce cooling needs, deploying energy management software and adopting environment-friendly designs.

Virtualization to reduce numbers of servers, power and disposal requirements*:* Virtualization is the masking of server resources, including number and identity of physical servers, processors, and operating systems, from users. The server runs a software to divide one physical server into multiple isolated virtual environments. Today, virtualization has turned into a primary scheme for growing business computing needs. It's fundamental objective is computing optimization in terms of energy efficiency and cost reduction. It improves the utilization of existing IT resources while reducing energy consumption, capital spending and human resource costs. For instance, virtualization enables increased server utilization by pooling applications on fewer servers. For large data centers, server usage ranges from 5-10% of capacity on average. With virtualization, server workloads can be increased to 50-85% where they can operate more energy efficiently [41]. Thus, less servers are required that means less power consumption, smaller server footprints, lower cooling costs, less headcount, and improved manageability.

Software program efficiency*:* The complexity and efficiency of any software program has direct impact on the amount of computer resources required for any given computing tasks. An efficient algorithm requires less computer resource and hence consumes less power. A study at Harvard, estimated that the average Google search releases 7 grams of carbon dioxide, half of boiling a kettle of water [42]. However, Google disputes this figure, arguing that a typical search produces only 0.2 grams of CO_2. Google search engine deploys very efficient searching algorithm — a typical search returns results in less than 0.2 seconds and consumes 0.0003 kWh of energy per search, or 1 kJ. For comparison, the average adult needs about 8,000 kJ a day of energy and, a Google search engine uses an amount of energy that our body burns in ten seconds [43].

LCD display and terminal servers*:* Instead of a traditional cathode ray tube (CRT) monitor, we need to use energy efficient liquid crystal display (LCD) monitors. According to the U.S. Department of Energy, LCDs are up to 66% more energy-efficient than CRTs. LCD monitors typically use a cold-cathode fluorescent bulb to provide light for the display. Some modern display systems use an array of light-emitting diodes (LEDs) in place of the fluorescent bulb, which reduces the amount of electricity used by the display. LCDs are also 80% smaller in size and weight, leading to fuel savings in shipping and produce less heat, meaning we will need less cooling. With terminal servers, users connect to a central server and end-users experience the operating system on the terminal. All the computation work is done at the server level, which use up to one-eighth amount of energy of a normal workstation, resulting in a less energy consumption.

Materials recycling*:* Recycling things involves using a product, in part or as a whole, in the production of similar or same products again. Recycling computing materials can keep harmful and destructive materials out and can also replace equipment that would need to be manufactured, saving further energy and emissions. According to Silicon Valley Toxics Coalition, 80% of the post-consumer e-waste collected for recycling is shipped abroad to countries such as China and Pakistan [44]. Recycling of old computers raises an important privacy issue. The old storage devices still hold private information, such as emails, passwords, and credit card numbers, which can be recovered. So, before recycling a computer, users should remove the hard drives and physically destroy it (e.g. melt it or break it into pieces) or store it somewhere safe. There are some authorized hardware recycling companies to whom the computer may be given for recycling, and they normally sign a non-disclosure agreement.

Operating system support*:* The Microsoft Windows operating system has included PC power management features since Windows 95. Further it added hibernate (suspend-to-disk) and support for the Advance configuration power Interface (ACPI) standard. Windows 2000 was the first operating system to include power management. The recently release, Windows 7, include refinements for more efficient user of operating system timers, processor power management and display panel brightness.

There is a significant market in third-party PC power management software offering features beyond those present in the Windows operating system.

Replace only required bits needed: If you are thinking to replace a computer, replace only those parts which really need replacement. Don't replace old monitor, keyboard and mouse if they are working – buying a complete computer when you have perfectly serviceable other parts is a waste of money.

6. GREEN COMPUTING STANDARDIZATIONS AND COMPLIANCES

The Organisation for Economic Co-operation and Development (OECD) has published a survey of several government and industry initiatives on green ICT to avoid the environment and climate change. Many government agencies have proposed to execute certain policies that support green computing [45]. Green computing can lead to reduction in energy costs from servers, cooling, and lighting. Present IT industries rely upon a complex networks and hardware but the green computing project should be universal and simple in nature. The solution towards green computing should comprise items such as end user satisfaction, management reformation, regulatory obedience, proper disposal of electronic scrap and waste, telecommuting, and virtualization of server resources, energy use, thin client solutions, and return on investment (ROI). Many nations worldwide have initiated some Standards and Regulations for energy-management programs, a few are as follows:

6.1. VIA Technologies Regulations

VIA also implemented a set of internal regulations in order to develop products without using hazardous materials in its production of chipsets and processors. In 2001, they focused on lead-free manufacturing, introducing the Enhanced Ball Grid Array (EBGA) package for power efficient VIA processors and the Heat Sink Ball Grid Array (HSBGA) package for their chipsets. In traditional manufacturing processes, lead is used to attach the silicon core to the inside of the package and to facilitate integration onto the motherboard through tiny solder balls on the underside of the package. VIA's lead-free manufacturing technologies do not require a lead bead and the solder balls now consists of a tin, silver, and copper composite [46].

6.2. Energy Star

It is an international standard for energy-efficient electronic equipment that was created by the United States Environmental Protection Agency in 1992 and is now adopted by several countries. Energy Star signifies the amount of energy consumed by a product and gets automatically switched into “sleep” mode when not in use. It is noted that most of the energy used by products on standby does not result any useful function. In Australia, standby power is a key factor for increased greenhouse gas emissions — more than 5 megatons (CO_2 equivalent) annually. Worldwide, standby power is estimated to account for as much as 1 percent of global greenhouse emissions. Energy Star enabled products can minimize this waste [46] [47].

6.3. Restriction of Hazardous Substances Directive (RoHS) Computing

In February 2003, the European Union adopted the Restriction of Hazardous Substances Directive (RoHS). The legislation restricts the use of six perilous materials in manufacturing various types of electronic and electrical equipments. The directive is closely linked with the Waste Electrical and Electronic Equipment Directive (WEEED) that sets collection, recycling, and recovery targets for electrical goods and is part of a legislative initiative that aims to reduce the huge amounts of toxic e-waste. A Taiwanese company that manufactures motherboard chipsets, CPUs, and other computer hardware, introduced the initiative for "green computing" in 2001. The company has been focusing on eco-friendly design and manufacturing process with better efficiency of its products. In spite of clean-computing strategies, the company is also determined to aware markets on the benefits of green computing for sake of the environment, as well as productivity. The other focused areas are carbon-free computing, solar computing, lead-free and energy-efficient computing [48].

6.4. China Energy Conservation Program

In 1998, the China National Development and Reform Commission (NDRC) founded the China Energy Conservation Program (CECP), a non-profit organization to administer, manage, and implement the certificate for energy- conserving, water-saving, and environmentally friendly products. CECP is committed to encouraging manufacturers to develop resource efficient products and help consumers for sustainable purchase decisions. CECP undertakes various projects of national and the international arena and plays actively for improving efficiency and environmental protection [49] [51].

6.5. Energy Conservation Center, Japan

In Japan, the Energy Conservation Center is dedicated for raising public awareness on energy

conservation, training and state examinations for energy managers, and their energy-conservation campaign and exhibition (ENEX) [49] [52].

6.6. EPEAT

Electronic Product Environmental Assessment Tool (EPEAT) is a powerful tool for environmental rating that helps to identify green computers and other electronic equipment. The EPEAT system was conceived and developed in collaboration with the stakeholders from the business, advocacy, government and academic arenas. EPEAT is used by several countries to showcase and certify greener designs and cleaner production. EPEAT registered products are almost free of environmental hazards across their lifecycles—from fewer toxins in manufacturing to efficient operation and easier recycling. EPEAT's searchable registry makes it easy to research a wide range of options while purchasing specifications, and work toward sustainability requirements with confidence. It provides a search for products by region and compares multiple options head-to-head. Search by optional criteria, such as mercury elimination or recycled content and to identify products that meet specific policy or regulatory requirements can also be done [53].

6.7 TCO 95 (Sweden)

The Confederation of Professional Employees, Tjänstemannens Central-Organisation (TCO) in Sweden has launched a series of initiatives in partnership with government and private organizations to protect environment and sustain development in the agencies where computers and office equipments are used. The "6E" is the latest and broad series of project by the TCO's development unit to eliminate unhealthy, poor or environmentally-incompatible equipment and practices from offices and other workplaces. It combines good environmental practice with sound business economics, and provides an overall approach whereby companies and organizations can integrate considerations relating to ecology and the work environment into everyday decision-making. It establishes environmental standards from purchasing of products and services, to the work process and environment. The "Six E's" symbolize high standards in ergonomics, economy, ecology, emissions, efficiency, and energy [63].

6.8 Blue Angel

The Blauer Engel (Blue Angel) is the first environment-related German certification for products and services in the world. It was created in 1977. The Blue Angel logo was adopted from the UNEP logo (United Nations Environment Programme), which was created in 1972. The Blue Angel is the property of the Federal Ministry of the Environment, Nature Protection and Nuclear Safety. It is sponsored and administered by the Federal Environmental Agency and the quality assurance [64].

6.9 Manufacturing Resource Planning (MRP II)

It is a system of standards, which regulate limitation on radiation from electrostatic, electrical and magnetic fields for computer and office techniques and was accepted by SWEDAC (Swedish National Board for Measurement and Testing - by National department of standards of Sweden) in 1990 [63].

6.10. Climate Savers Computing Initiative

It was started by Google and Intel in 2007 and is a non-profit group of eco-conscious consumers, business and conservation organizations. It was started in the spirit of WWF's climate savers program which has mobilized over a dozen companies since 1999 to reduce carbon dioxide emissions. Its main objective is to promote development and adoption of smart technologies that can improve the efficiency of a computer and reduce the energy. Also, its mission is to reduce global CO_2 emissions from the operation of computers by 54 million tons per year, equivalent to the annual output of 11 million cars [50].

6.11. ISO Standardizations

ISO 14001 is a tool that comes in the form of a combined handbook and CD and was published in 1996 and then revised in 2004 has proved very successful. It is now implemented in more than 159 countries and has provided organizations with a powerful management tool to improve their environmental performance. Several organizations have been certified worldwide against ISO 14001. Many companies have improved their operations and reduced the impact of their activities, processes, products and services on the environment by using a systematic approach that seeks continual improvement. The ISO 14064 and ISO 14065 standards for greenhouse gas accounting and verification are integrated set of tools for programmes aimed at reducing greenhouse gas emissions, as well as for emissions trading [54].

ISO 14066 is the another latest document in the ISO toolbox of standards to address climate change and GHG emissions. It was launched in 2006 with

ISO 14064, a three-part standard for assessing green house gases (GHG) emission reduction projects in either voluntary or regulatory schemes. The standard was followed by ISO 14065, which gives accreditation requirements for organizations that validate or verify resulting GHG emission assertions or claims. Dr. Tod Delaney, Convenor of the ISO working group responsible for ISO 14066, commented: "The accuracy of an organization's GHG emissions claims is essential, considering the political and financial ramifications of each claim" [55].

Green Computing Certifications and Programs

6.12. Energy Savings Certificates

Energy savings certificates (ESCs) are used in some nations as a system through which third parties, such as commercial and industrial companies, can help utilities to meet with energy efficiency targets. These certificates keep track of the measurement and verification of the actual reduction in energy usage [56].

6.13. Green Computing Programs

Several programmes are conducted every year throughout the world in an effort to educate people to build and maintain systems while reducing its negative impact on the environment. The Australian National University (ANU) offers "ICT Sustainability" as part of its information technology and engineering masters programs [57]. Athabasca University offer a similar course "Green ICT Strategies" [58], adapted from the ANU [59]. In UK, Leeds Metropolitan University offers an M.Sc. program on green computing in both full and part time access modes [60].

6.14. GOST 27954-88

It is the Russian standard on video monitors for personal computers. The requirements of this standard are mandatory for any monitor sold in Russian Federation. The screen monitors of personal computers and workstations at mandatory certification are exposed to certification tests on the following parameters:

1. Parameters of safety - electrical, mechanical, fire (GOST 50377-92);
2. Sanitary-hygienic requirements - to a level of sound noises (GOST 26329-84 or GOST 2718-88), indexes ultra-violet, X-ray radiation and quality of the image (GOST 27954-88);
3. Electromagnetic compatibility - radiated radiointerferences (GOST 29216- 91).

The certificate is produced only on all complex set of aforesaid GOSTs [63].

6.15. OHSAS 18001

OHSAS 18000 is an international occupational health and safety management system specification. It comprises two parts, 18001 and 18002 and embraces a number of other publications. It is intended to help an organization to control occupational health and safety risks. It was developed in response to widespread demand for a recognized standard against which to be certified and assessed [65].

7. CONCLUSIONS

The aim of this paper is to focus on the sustainable IT organizations with effective energy efficiency and negligible environmental problems. Green computing leads to a spectacular change in the IT industry. Thus far, the IT industries has been focusing on electronic equipment processing only. The concern with other requirements such as power, cooling, and data center space is very less. However, recent developments IT industry indicates the motivation and certainty to deal with the environmental issues.

This paper exhibits a review of current thinking and suggested factors that should be considered for a sustainable IT strategy. Hence, it is concluded that the IT equipment industries can play a significant role in green computing movement. Major IT industries have evolved their devices for better efficiency and cooling requirements by providing tools that can monitor equipment and data center power usage, and can organize the power necessity to IT equipment and monitor equipment temperature conditions to help discover and address data center cooling issues, or control data center cooling based on heat loads. Energy Star has already set up and the European union is also committed to achieve major green computing goals for the energy-hungry centers.

Some challenges that the society is facing regarding green computing are:

- The greatest challenges for the society is to get understanding about the objectives of green computing and then only the environment can be sustainable.
- Another challenge is to decrease the pressure on environment. International Standards like ISO-14000 and Occupational Health and Safety Standard (OHSAS-18001) on environment management are already designed and that needs

to be implemented properly. These standards provide an outline and direction for accessing the IT related risk, nature of that risk and required control of measures. These are the good practices for implementation of Green computing initiatives [61][62].

- Scrap due to constant use of IT has enormously increased. There is no standard policy to degrade and reuse the scrap. The scrap material collected by scavengers should be disposed properly. In this regards, government should provide strong guidelines to collecting agencies and if required practical training for disposal as per regulations, so as to maintain green revolution in future.
- It is necessary that appropriate awareness campaigns and initiatives should be taken at different levels to extend this concept.

There is a need of an efficient model for the development and implementation of sustainable computing services.

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References

[1] Frances Cairncross, "Costing the Earth: The Challenge for Governments, the Opportunities for Business," Harvard Business School Press, 1992.

[2] S. Agarwal and A. Nath, "Green Computing - A New Horizon of Energy Efficiency and Electronic Waste Minimization: A Global Perspective," Proc. IEEE in International Conference on Communication Systems and Network Technologies, pp. 688-693, 2011.

[3] Matti Tedre, Bukaza Chachage, and Joy Faida, "Integrating environmental issues in IT education in Tanzania," Proc. IEEE in Frontiers in Education Conference (FIE '09), pp. 1-7, 2009.

[4] R. Raghavendra, P. Ranganathan, V. Talwar, Z. Wang, and X. Zhu, "No power struggles: Coordinated multi-level power management for the data center," Proc. In 13th international conference on Architectural support for programming languages and operating systems (ASPLOS XIII), pp. 48-59, 2008.

[5] S. Ruth, "Green IT More Than a Three Percent Solution?," IEEE Trans. Internet Comput., vol. 13, no. 4, pp. 74-78, 2009.

[6] Xinying Zheng, Yu Cai, "Energy-aware load dispatching in geographically located Internet data centers," Sustain. Comp: Inf. Sys., vol. 1, pp. 275– 285, 2011.

[7] S. Murugesan, "Harnessing Green IT : Principles and Practices," J. Inf. Technol., vol. 10, pp. 24-33, 2008.

[8] Brian Donnellan, Charles Sheridan and Edward Curry, "A Capability Maturity Framework for Sustainable Information and Communication Technology," IT Professional, vol. 13, pp. 33–40, 2011.

[9] Bing Shi, Ankur Srivastava, "Unified datacenter power management considering on-chip and air temperature constraints," Sustain. Comp: Inf. Syst., vol. 1, pp. 91-98, 2011.

[10] Today's road to e-Commerce and Global Trade Internet Tech. Reports, http://www.internetworldstats.com/stats/htm.

[11] R. R. Harmon and N. Auseklis, "Sustainable IT services: Assessing the impact of green computing practices," Proc. In Portland International Conference on Management of Engineering & Technology (PICMET 09), pp. 1707-1717, 2009.

[12] Subramanian Chitra, "Adopting Green ICT in Business," Green Technologies: Concepts, Methodologies, Tools and Applications, IGI Global, pp. 1145-1153, 2011.

[13] Chris Hendrickson, Noellette Conway-Schempf, Lester Lave and Francis McMichael, "Introduction to Green Design." Green Design Institute. http://gdi.ce.cmu.edu/education/courses.html.

[14] W. J. Glantschnig, "Green design: an introduction to issues and challenges," IEEE Trans. Compon., Packag., Manuf. Technol.A, vol. 17,pp. 508-513, 1994.

[15] W. Glantschnig, "Green design: a review of issues and challenges," Proc. In IEEE International Symposium on Electronics and the Environment, pp. 74-78, 1993.

[16] T.E. Graedel and B.R. Allenby, "Industrial Ecology," *Prentice Hall*, 1995.

[17] William H. Kemp. The Renewable Energy Handbook: A Guide to Rural Energy Independence, Off-Grid and Sustainable Living. *Aztext Press*, 2006.

[18] Office of Technology Assessment. Green Products by Design. *US Congress, OTA-E-541*, Washington, DC, 1992.

[19] Manufacturer's Association for Information Technology, 2008.

[20] M. Deif Ahmad and S. K. Regina, *Adv. Prod. Eng. Manag*., 6, 7-36 (2011).

[21] Graedel, T.E. and B.R. Allenby, "Industrial Ecology," *Prentice Hall*, 1995.

[22] K. Brigden and D. Santillo. Greenpeace Research Laboratories Technical Report, 2006.

[23] Panyaluck Udomleartprasert, "Roadmap to Green Supply Chain Electronics: Design for Manufacturing Implementation and Management," Proc. In International IEEE Conference on the Asian Green Electronics, pp. 169-173, 2004.

[24] Baoju Han and Jian Liu, "Virtual green manufacturing and its application in manufacturing," Proc. in IEEE conference of Mechanic Automation and Control Engineering (MACE), pp. 917-919, 2011.

[25] Jennie S. Hwang, Zhenfeng Guo , Holger Koenigsmann, "A high-performance lead-free solder – the effects of In on 99.3Sn/0.7Cu," Solder. Surf. Mt. Tech., vol. 13, pp. 7-13, 2001.

[26] Vazifehdust Hussein and Asadollahi Amin, "The Role of Green Marketing in the Recycling of Electronic Case Study: Computer and Mobile to Iran," Eur. J. Soc. Sci., vol. 23, no. 4, pp. 559-566, 2011.

[27] Yoshiharu Kariya, et al, "Tin Pest in Lead-Free Solder," Solder. Surf. Mt Tech., vol. 13, no. 1,2003, pp. 39-40, 2003.

[28] Peter Collier, et al, "Lead-Free Solder Process

Implementation for PCB Assembly," Solder. Surf. Mt. Tech., vol. 14, no. 3, pp. 12-18, 2002.

[29] Campus Computing and the Environment Report of the Green Computing Task Group to the Information Services Committee (ISC) Final Report, 2006, http://www.isc.uoguelph.ca/documents/061211GreenComputingFinalReport2006_000.pdf

[30] M. Talebi and T. Way, "Methods, metrics and motivation for a green computer science program," Proc. In 40th ACM technical symposium on Computer science education - SIGCSE '09, ACM, pp. 362-366, 2009.

[31] Power usage, http://www.pcpower.com/technology/power_usage/

[32] Les Citrome, "Creating a more productive, clutter-free, paperless office: a primer on scanning, storage and searching of PDF documents on personal computers," Int. J. *Clin. Pract.*, vol. 62, no. 3, pp. 363-366, 2008.

[33] Daniel P. Dern. Power plug meters help save money, energy. *Computer world*, Aug. 27, 2008. http://www.computerworld.com

[34] William H. Kemp. The Renewable Energy Handbook: A Guide to Rural Energy Independence, Off-Grid and Sustainable Living. *Aztext Press*, 2006.

[35] Liu Li Na, "Green Manufacturing - New industrial development in China," J. *Renewable Resources*, vol.3, 2009.

[36] Recycling Why it's important and how to do it, friends of the earth, 2008. http://www.foe.co.uk/resource/briefings/recycling.pdf

[37] Elizabeth Grossman. High Tech Trash: Digital Devices, Hiddent Toxics, and Human Health. *Island Press*, Washington, 2006.

[38] S. Pelley, D. Meisner, T.F. Wenisch, and J.W. VanGilder, "Understanding and abstracting total data center power," Proc. In Workshop on Energy Efficient Design (WEED), 2009.

[39] W. Forrest, J. M. Kaplan, and N. Kindler, "Data Centers: How to Cut Carbon Emissions and Costs," The McKinsey Quarterly, Winter 2008.

[40] D. Capuccio and L. Craver, "The Data Center Power and Cooling Challenge," *The Gartner Group*, 2007.

[41] L. A. Barroso, and U. Hölze, "The Case for Energy-Proportional Computing," *IEEE Computer Society*, pp. 33-37, 2007.

[42] Research reveals environmental impact of Google searches, Fox News. 2009-01-12, http://www.foxnews.com/story/0,2933,479127,00.html

[43] Powering a Google search". Official Google Blog. Google, 2009, http://googleblog.blogspot.com/2009/01/powering-google-search.html

[44] Royte, Elizabeth *(*2006*). Garbage Land: On the Secret Trail of Trash*. Back Bay Books. pp. 169–170.

[45] OECD (2009a), "Towards Green ICT Strategies: Assessing Policies and Programmes on ICT and the Environment", *OECD*, Paris, www.oecd.org/dataoecd/47/12/42825130.pdf.

[46] Green Computing: The future of things, http://thefutureofthings.com/articles/1003/green-computing.html

[47] Arpad Horvath and Eric Masanet, "Enterprise Strategies for Reducing the Life-Cycle Energy Use and Greenhouse Gas Emissions of Personal Computers" Proc. In IEEE International Symposium on Electronics and the Environment, pp. 21-26, 2006.

[48] VIA Green Computing Initiative, http://www.via.com.tw/en/initiatives/greencomputing/

[49] VIA Technologies Green Computing: http://thefutureofthings.com/articles/1003/green-computing.html

[50] Climate Savers Computing Initiative: http://www.climatesaverscomputing.org/

[51] China Energy Conservation Program (CECP) http://www.cecp.org.cn/englishhtml/index.asp.

[52] The Energy Conservation Center, Japan. http://www.asiaeec-col.eccj.or.jp/index.html.

[53] Work toward environmental goals through IT purchasing, http://www.epeat.net/who-are you/purchaser/governmentinstitutional

[54] Management and leadership standards, http://www.iso.org/iso/iso14000essentials,

[55] Product ISO Standards–TC207 Environmental Management, http://www.iso.org/iso/catalogue_detail?csnumber=43277

[56] Energy Saving certificate: http://www.cosn.org/initiatives/greencomputing/otherresources/greenenergyuse/greencertificates/tabid/4663/default.aspx

[57] ICT Sustainability Course, Australian National University, 2012, http://studyat.anu.edu.au/courses/COMP7310;details.html

[58] Green ICT Strategies (Revision 1), Athabasca University, 2011, http://scis.athabascau.ca/graduate/comp635syllabus.php.

[59] ICT Sustainability: Assessment and Strategies for a Low Carbon Future, Tomw Communications Pty, Limited. 2011-09-06, http://www.tomw.net.au/ict_sustainability/

[60] MSc Green Computing Course, Leeds Metropolitan University, 2012, http://courses.leedsmet.ac.uk/greencomputing_msc.

[61] D. Wang and D. Ph, "Meeting Green Computing Challenges," *Proc.in HDP*, pp. 6-9, 2007.

[62] R. Harmon, H. Demirkan, N. Auseklis, and M. Reinoso, "From Green Computing to Sustainable IT: Developing a Sustainable Service Orientation," *Proc.* In 43rd Hawaii International Conference on System Sciences , pp. 1-10, 2010.

[63] Standards, http://library.thinkquest.org/C0123325/sta.htm

[64] The German Blue Angel: The first eco symbol for products and services, 2008, http://infomancie.wordpress.com/2008/01/03/the-german-blue-angel-the-first-eco-symbol-for-products-and-services/

[65] OHSAS 18001, Health & Safety Zone, http://www.ohsas-18001-occupational-health-and-safety.com/what.htm