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# TRANSITION TO GREEN ICT: TRENDS AND CHALLENGES

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**Abstract:**

Today almost every individual as well as every Organization is fully dependent on ICT (Information and Communication Technology) for its day to day functioning. In fact ICT has helped a lot in reducing $CO_2$ emissions by replacing physical movements with information movements, thereby reducing the consumption of energy and materials. It has promoted services such as telecommuting, distance education, remote learning, telemedicine, teleconferencing, E-Commerce, E-Governance etc. But according to Gartner report, the total Carbon footprint of ICT sector itself is expected to reach to 6% of the total emissions from human activity by the year 2020. Energy Conservation is one of the greatest challenges today. In the field of Computing, the emphasis earlier was on faster analysis and faster calculation of complex problems. Recently, this focus has shifted towards achievement of energy efficiency, minimization of power consumption, use of non-toxic materials for making e-equipment and reuse and recycling of equipment. Ever increasing energy crisis has led towards Green Computing. Target of green computing is minimizing environmental cost in use of ICT solutions. In this paper, several green initiatives currently under way in the computer industry has been discussed along with the issues that have been raised regarding these initiatives. This paper also suggests some fundamental steps that can be taken to significantly decrease the environmental impact of ICT. This paper reviews some of the issues related to Green ICT and encourages the professional ICT community to play an active role in the transformation of ICT to Green ICT in order to make ICT services environment friendly.

***Keywords:*** ICT, Green computing, Big Data, Cloud Computing, Networking, Green Algorithm, Energy Conservation.

## Introduction:

Ever since its invention in 1948, the computer has changed the world. Originally designed to be used in World War II, almost every house today has its own computer. Supercomputers, which have an array of processors, consume power in quantities capable of running an electric train. This has an indirect impact on our environment, as electricity is not a renewable source of energy. Even when we leave our desktop open, it consumes a lot of energy. Earlier, this was not much of a worry, but as there has been an exponential increase in number of computers, the problem has increased tremendously. Similarly, today everything has gone online, be it e-bill, to e-learning, and many more. In 2012, every day 2.5 Exabyte (2.5×1018) of data were created online. The storage of this data needs more servers and data centers, which leads to greater energy consumption and waste generation.

Since most communication systems have to run 24/7, the energy consumption of a system is of great importance. Every computer requires about 1.8 tons of water, chemicals and fossil fuels for its manufacture. After starting its use, it emit about 0.1 ton of CO2 in a year. According to a research, computers generate an estimated 35 million tons of carbon dioxide into the atmosphere each year. After two or three years, every computer turns into junk. The junk computers are often dumped in landfills, which pollute the soil with poisonous elements like cadmium and mercury.

Now days we are heavily dependent on computers. Since the decrease in number of computers is not possible, efforts are being made to turn the computers green i.e., several corrective measures are being taken which help in minimizing the power usage of computers and this process is called as Green Computing.

The field of green computing is defined as the knowledge and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems—which include printers, monitors, and networking, storage devices and communications system efficiently and effectively with minimal or no impact on the environment.

Government sectors 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. Energy Star reduces the amount of energy consumed by a product by automatically switching it into sleep mode when not in use or reducing the amount of power used by a product when in standby mode. The electricity consumed by appliances when they are in standby mode, is almost 12 percent of a household's electricity consumption.

It is estimated that out of $250 billion per year spent on powering computers worldwide only about 15% of that power is spent computing while the rest is wasted idling. Taking into consideration the popular use of ICT, energy saved on computer hardware and computing will equate tons of carbon emissions saved per year.

Currently the ICT industry is responsible for 3% of the world's energy consumption. With the rate of consumption increasingly by 20% a year, 2030 will be the year when the world's energy consumption will double because of the ICT industry.

It is generally believed that by switching from paper to electronic mode of communications, we are going green, and that in doing so we save paper and thus done a bit to save the environment and generate less CO2. In Europe's largest IT infrastructure company, Mr. Matthew Yeager of Computer Centre claims that an e-mail of 1 MB would be the equivalent to the emission of 19 grams of 2 and e-mails with attachments are worse. Yeager estimates that in a 100-people company where each employee sends on average 33 e-mails a day and receives 58, the greenhouse gas emission linked to emails would be around 13.6 tons of CO2 per year.

These staggering figures imply the need to transform ICT to Green ICT in order to ensure sustenance of the environment. Green computing can minimize the negative effect on the environment without compromising on modern-day needs. The goals and ideology of green computing are simple:

- Reduce the use of hazardous materials in manufacturing computing devices.
- Maximize energy efficiency during the product's lifetime.
- Promote the recyclability or biodegradability of unusable products and factory waste.

**Literature Review**

In their paper 'Green Computing Future of Liveliness', Sk. Fayaz Ahamad and P.V.Ravikanth have discussed the several approaches towards green computing and have mentioned following Applications which are already being used to conserve energy as initiatives under Green Computing. They are:

**Blackle**:

Blackle is a search-engine site powered by Google Search. It uses the concept that when a computer screen is white, presenting an empty word page or the Google home page, computer consumes 74W. When the screen is black it consumes only 59W. Based on this theory if everyone switched from Google to Blackle, the World would save 750MW each year. This was a really good implementation of Green Computing. The principle behind Blackle is based on the fact that the display of different colors consumes different amounts of energy on computer monitors.

**Fit-PC:**

It is a tiny PC that draws only 5w. Fit-PC is the size of a paperback and absolutely silent, yet fit enough to run Windows XP or Linux. Fit-PC is designed to fit where a standard PC is too bulky, noisy and power hungry. If anyone prefers compact, quiet and green PC then fit- PC is the perfect for them.

**Sunray thin client:**

Sun Microsystems has reported increased customer interest in its Sun Ray, a thin desktop client. According to Subodh Bapat, vice president and chief engineer in the Eco Responsibility office at Sun, Thin clients like the Sun Ray consume far less electricity than conventional desktops. A Sun Ray on a desktop consumes 4 to 8 watts of power, because most of the heavy computation is performed by a server.

**The Asus Eee PC and other ultra portables:**

The ultra-portable class of personal computers is characterized by a small size, fairly low power CPU, compact screen, low cost and innovations such as using flash memory for storage rather than hard drives with spinning platters. These factors combine to enable them to run more efficiently and use less power than a standard form factor laptop.

Today's mobile phones are capable of doing it all, rather sometimes more than the traditional phones. They have faster processors, more ram, faster wireless Internet connectivity and larger memories. Mobile Phones consume very low power.

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.

**Initial Findings:**

The Council of European Professional Informatics Societies launched CEPIS GREEN ICT survey in 2011 which aimed at finding the energy consumption and efficiency pattern of ICT equipment in various organizations of European Union. The initial findings were:

- 75% of organizations do not have a specific person or team dedicated to the task of Green Computing in their office.
- 33% of the organizations do not implement Green IT practices. They have no official legislation in place.
- 50% of Organizations donate old PCs to recycling companies while 20% donate it to charities
- 67% of Organizations use recycled cartridges for printers.
- There is a definite lack of awareness of interrelation between technical, economic and environmental aspects of ICT

Following issues result in worsening of situation and these must be resolved for ensuring sustainability of ICT.

- Lack in transparency of energy costs in ICT services- Now a days there is almost no correlation between price of a service and the energy cost it creates. When this divergence is quite a bit then there will definitely be dire consequences. An example of this is very low flat rate for accessing internet while high cost of SMS. For instance, the email spam caused worldwide in 2008 consumed 33TWh of power which is more than annual power generation of Bangladesh. If the sender of the spam had to bear the energy cost of this, he definitely would not have done this and there wouldn't be any spam in circulation.
- Material Demand of ICT hardware production- A variety of materials contained in ICT Hardware makes recycling difficult. Today 57-60 chemical elements are used to build microprocessors. In 1980s only 12 elements were used. Miniaturization and integration work against Recycling.
- Low understanding of role of good Software engineering processes- Very few Organizations and individuals are aware of green Software Engineering Processes which result in development of efficient software which utilize the resources efficiently and result in consuming less energy.

**Suggestions**

**Green Cloud Computing**

Cloud computing has established itself as an enabling technology for multiple IT services. The increase in the number of cloud-based IT services and applications demands establishment of data centers that house thousands of web servers, storage, and network devices. Cloud data centers provide a range of services from high-performance computing to large-scale data analytics to end users. The massive scale of cloud data centers that are setup at multiple geographical locations to facilitate distributed users means that they contribute 25% to the total IT electricity share. Moreover, IT services are shifting from single server operations to rack-mounted blade servers. The rack-mounted server designs result in higher electronic densities, higher energy consumption, and heat dissipation. As a result, both direct energy and indirect cooling energy demands rise in cloud data centers. The techniques to “green” cloud data center operations can be broadly classified into three categories:

- Resource management with Virtualization
- Sustainability with renewable energy and Waste heat utilization
- Resource scheduling with Evolutionary Algorithms.

Cloud data center resources are managed by a virtualization layer that resides over the physical resources. The virtualization layer abstracts the hardware layer interfaces to provide a higher level interface for users and applications. The virtualization layer helps in management and consolidation of cloud data center resources through multiple backup techniques, such as resource migration and snapshot. The primary objective of virtualization in cloud data centers is to provide scalable and fault-tolerant operations. Increasingly, virtualization is being used for resource consolidation and energy efficiency. A virtual resource residing on a 40% utilized server can be migrated to another 40% utilized server while the former is operated in low-power idle mode. However, the network cost resulting from the VM migration needs to be addressed for joint network and server resource optimization.

The green computing initiative also embodies sustainability in operations. Cloud data centers operating on renewable energy resources lead to zero GHG emissions. Renewable energy from sources such as the sun and the wind can be generated from on-site installations or purchased from off-site corporations. The main drawbacks of renewable energy based cloud data center operations are the associated cost and unpredictable supply of the renewable resource. It is estimated that with the advances in storage capacities, the cost/Watt of renewable energy will halve in the next decade. Moreover, to address the unpredictability of renewable energy resources, techniques such as dynamic power-workload balancing and server power capping are exploited.

The waste heat generated by data centers can be utilized or re-used in various waste heat recovery scenarios. Firstly, cloud data centers provide ample opportunity for waste heat re-use in the cooling process. The heat recovered from servers is captured in the vapor-absorption based cooling systems where reversible heat pumps transfer thermal energy to cooler space. Secondly, in cooler places, data centers can be co-located with residential buildings for district heating. Thirdly, modular data center designs can be migrated to cooler areas to reduce the cooling requirements while directly utilizing ambient air in the cooling process.

The basic objective of cloud data centers is to provide IT services at an optimal pay-as-you-go model. Recently, with a shift in focus on the energy consumption, the energy costs have been included in the optimization models.

Evolutionary algorithms are employed to swiftly find near-optimal solutions for the multi-objective energy efficient resource scheduling problems in cloud data centers.


Fig. 1

Green Cloud Computing Techniques

**Green Mobile Computing**

Smartphones of recent generations are equipped with high storage capacity and the computational power to perform resource-intensive tasks. The preference of smartphone users has lessened the dependency on desktop servers to perform computing tasks. As a result, the resource requirements of the smartphone applications have also increased. Emerging media-rich smartphone applications frequently trigger sensors, such as GPS, accelerometer, and wireless radios to provide context-aware services. As a result, the computation, communication, and energy cost of smartphones significantly increase. To handle the energy-performance trade-off, energy-efficient system designs are necessary to meet the requirements of modern smartphone devices.

The architectural design of hardware modules within the smartphone is based on Complementary Metal–Oxide–Semiconductor (CMOS). The total power consumption of CMOS based circuits (e.g. CPU, static RAM, and GPU) consists of static and dynamic power. The static power of a circuit varies from device to device depending on the insulation capabilities of transistors and represents the power consumption when the transistor is not in the switching state. Dynamic power represents the power consumption when a device changes logic state from on to off or vice versa. Power gating embeds a high voltage threshold transistor between actual ground and circuit ground of a device to switch off the transistor during its sleep hours to reduce leakage power. For the CPU module, dynamic frequency scaling (DFS) enables dynamic adjustment of power consumption for greening the smartphones at the cost of throughput. The tail power state of smartphone components such as Wi-Fi, 3G, GPS, and SD-CARD, depletes battery charge quickly. Software tools, such as E-prof, empower smartphones to measure/estimate the device energy consumption at the component level.

Software based green computing solutions such as mobile cloud computing based computational offloading, energy bug handling, and energy efficient application development significantly reduce the energy budget of the smartphone. Mobile cloud computing empowers smartphone devices to augment device lifetime by carefully offloading energy critical tasks to remote cloud servers.

Energy bugs within a smartphone lead to abnormal power consumption behavior of mobile applications. Energy bugs are difficult to track, and mainly occur due to **(a)** faulty batteries, **(b)** damaged mobile battery chargers, **(c)** infected memory cards, and **(d)** damaged SIM cards.

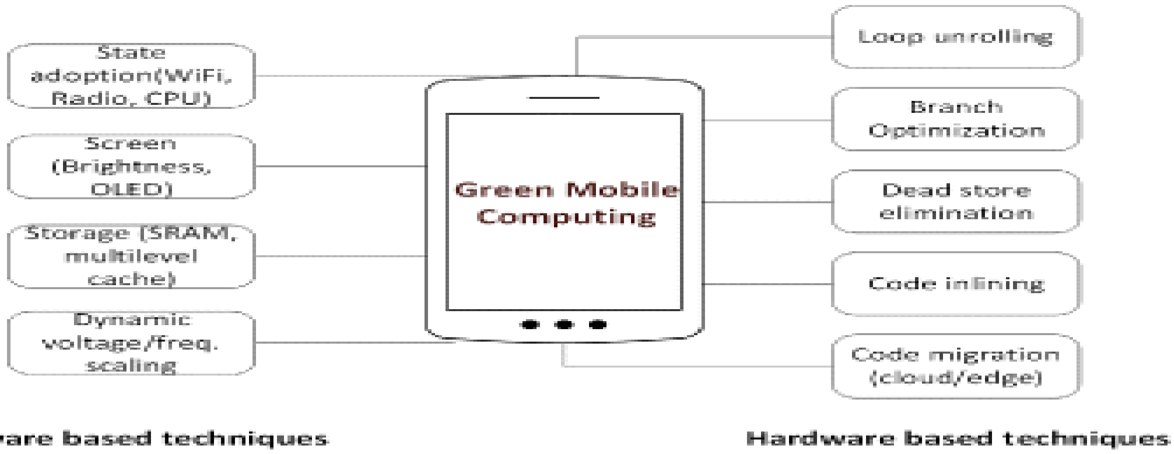


Fig. 2

Green Mobile Computing. The figure depicts techniques for green mobile computing

Inefficient code design within a smartphone application has a high impact on the total energy consumption. Within an application, resource optimal placement of classes and functions reduces the power consumption. For instance, minimizing the memory distance between two functions that frequently communicate reduces the energy consumption of target application. Also, educating developers with energy efficient application development techniques including loop unrolling, branch optimization, dead store elimination, value numbering, code inlining, constant propagation, code motion, inter-procedural analysis, and instruction scheduling.

**Green Big Data Analytics**

Big data introduces the era of data with new challenges such as petabyte scale structured and unstructured data sets which are growing at an exponential rate and have heterogeneous formats. Fast data retrieval and accuracy of search from a pool of big data are the main challenges to maximize value for decision making in big data analytics. Traditional data management systems lack the capability to handle big data storage and analytics requirements. The process of greening is crucial for big data as analytics on tremendous size of data sets requires high computing power, scalable and efficient storage space, high availability of main memory, and fast communication media on always-on local physical or enterprise cloud servers.

Cloud computing is revealed as a big data analytics technology which offers resource outsourcing in order to avoid physical occupation and thus multiple users with varying analytics requirements can utilize remotely accessible resources. Along with resource preservation, cloud computing also offers lower energy consumption for executing high computational procedures on big data.

There is a visible advancement in today's technology towards green big data analytics. For instance, GreenPlum and GreenHadoop are proposed in big data analytics for green computing. GreenPlum is an open source data warehouse, licensed under Apache Inc., which offers fast analytics on petabyte-scale data with efficient query processing via parallel processing and optimization. Cost-based query optimization introduced by GreenPlum ensures high analytics on large volume data sets with usage efficiency.

GreenHadoop, on the other hand, brings the idea of renewable energy sources in order to balance the supply and demand of energy sources associated with big data analytics. The GreenHadoop framework uses a photovoltaic solar array and electrical grid energy resources. The GreenHadoop framework for green analytics achieves maximized energy consumption by estimating available solar energy and scheduling MapReduce jobs accordingly.

Figure 3 shows a green big data analytics process where storage and processing resources reside on clouds and can be requested on demand. Currently, major big data sources and consumers are social networks, healthcare, industries, commerce, and business enterprises. Data from these sources and consumers is extensively scalable and brings critical analytics requirements for timely decision making. This big data storage and processing load are efficiently handled by data centers and processors residing on the cloud which ensures green analytics. According to a study, it is estimated that cloud computing will be able to achieve 38% reduction in energy usage by 2020. The concept of recycling suggests that renewable energy technology will be a preferable choice of investment in finding energy resources by 2040.

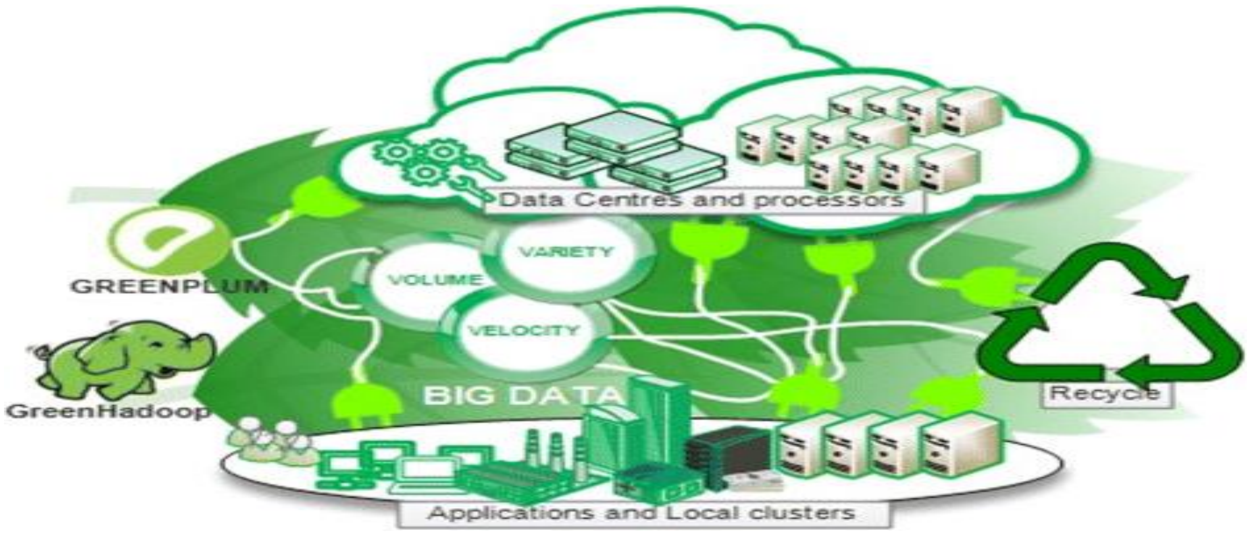

Fig. 3 Green Big Data Analytics. The figure depicts techniques for green big data analytics

**Green networking**

As more industries and business have integrated IT technologies and services, the networks have grown into complex structures connecting billions of devices worldwide. As a result, network devices consume a large amount of energy constituting approximately 10% of the aggregate IT energy consumption. The basic techniques applied for energy efficient networks are:

- energy efficient protocols for routing, medium access, hand-off
- Adaptive Link Rate (ALR) techniques that scale link rate and utilize sleep states for energy-proportional computing.

The software and virtualization techniques have led to current advancements in the energy efficiency of networking technologies. Software Defined Networks (SDN) separate the data and control plane of network routers with the help of a central controller. SDN do not have a direct impact on the energy consumption of a network. However, the pervasive programmable interface of SDN supports energy efficient network operations indirectly through resource consolidation. A minimum energy efficient subset of network resources can be calculated through a resource optimization technique and implemented through SDN. Hence, server and network resource management techniques can be utilized in parallel with the virtualization and SDN enabling technologies. SDN can help implement green computing policies at the network level based on their programmable control plane. Similarly, security policies can be implemented with the help of SDN while eliminating the need for stand-alone security devices, lowering the total operational costs and energy bill.

Network Function Virtualization (NFV) is another technological shift in telecommunication systems. NFV decouples network forwarding and routing functions from underlying physical systems through virtualization. Network functions, such as a firewall, can be implemented in software (virtual network function) and implemented on any of the industry standard physical servers. Similarly, network devices can offer virtual computation services. The decoupling of network functions from physical devices results in flexible and dynamic resource scheduling, hence, energy efficiency. However, a balance between network function performance and energy efficiency achieved through virtualization has to be resolved.

**Role of Computer users towards green computing**

Computer users can follow certain simple steps to slightly modify their usage habits. This will minimize the negative impact on the environment. Some examples are:

- Checking product information for energy-efficiency before buying.
- Buying only those products with specifications that suit your needs – for example, someone who uses mostly office software may not need high power graphic cards that are more suited for games.
- Switch off devices, including peripherals like printers, when not using for long periods.

- Limit power intensive usage like games and videos.
- Find an optimum display setting for monitors that will conserve energy.
- Reduce printing as much as possible. Print on both sides to reduce paper wastage.
- Periodically perform thorough maintenance checks on devices.
- Try to share additional storage such as hard-disks with others.
- Reuse accessories like chargers, etc. to the maximum extent possible.
- Dispose unusable computing devices responsibly by handing them over to e-waste disposal centres.
- Avoid buying newer products/versions unless necessary. The prospect of green computing is huge.

**Conclusion:**

In India, green computing has not yet had a major impact, even though it has been a topic of keen interest and research among scholars. Little application can be seen in practice. There has been no special course dedicated to green computing in Indian universities, though recently, some of them have added green computing as a part of the curriculum.

One major problems faced in India is the lack of awareness of green computing.

Proper regulations should be implemented by government laws to establish certain standards. Efficient storage of data should be made the norm for large corporate houses. Incentives must be given to companies that adopt. Customers should be informed about the effects of their actions.

Energy efficiency of ICT devices is increasing but the demand for ICT is increasing even more. The users are using this increased computing power regardless of the negative effect it is having on our Environment.

Reduction of Environmental impact of ICT is the need of hour. For this a new culture has to be encouraged. A deeper understanding of multifaceted relationship between ICT, society and nature is required to make our lives more sustainable. Awareness and responsible behavior are background condition to achieve sustainable ICT through Green Computing.

**References:**

1. *"us.ecocompass.com/blog/green-computing-technology-of-the-future" accessed on 25/8/2017.*
2. Ahad Abdullah(2014), "Green Cloud Computing- the need of the hour", Vol 2 International Journal of Research in Advent Technology.
3. Carol, Ann Kogelman, " CEPIS Green ICT Survey", European Journal for Informatics Professional.
4. Chaitali Patra, Dr. Asoke Nath(2014), "Green Computing- New Paradigm of Energy Efficiency and E-waste minimization", Vol 2 International Journal of Advance Research in Computer Science and Management Studies.

5. Gaurav Jindal, Manish Gupta, "Green Computing: Future of Computers"
6. Juan Carlos, Giovanna Sissa, " Green ICT for Environmental Sustainability", European Journal for Informatics Professional.
7. Juha Taina, "Good, Bad and Beautiful Software", European Journal for Informatics Professional.
8. Lorenz M, Wolfgang Lohmann, " Most Neglected Issues in Green IT", European Journal for Informatics Professional.
9. N. P. Jadhav, R.S. Kamble, S. V. Kamble, "Green Computing-New Approaches of Energy Conservation and E-Waste Management", IOSR Journal of Computer Engineering.
10. Navjot Kaur(2013), "Exploration of Green Computing", Vol 3 International Journal of Emerging Technology and Advance Engineering".
11. Parichay Chakraborty, Debnath, Sovan, Satfarova(2009), "Green Computing-Practice of efficient and Eco friendly Computing Resources", Vol 2 International Journal of Grid and Distributed Computing.
12. S. Jaya Prakash, Dr. K. Subramaniyam(2012), "Towards Energy Efficiency of Green Computing based on Virtualization, Vol2 International Journal of Emerging Trends in Engineering and Development.
13. S. K. Fayaz Ahmad, P.V. Ravikanth, "Green Computing-Future of Liveliness", International Journal of Computational Engineering Research, ISSN:2250-3005.