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Perspectives of Green Computing

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Abstract

Green computing has been in the focus since past years by public and private organizations. This review based study focuses on introduction of Green Computing, and describes historical and current issues and efforts made to progress in this field along with the hope for future in the field. It also mentions challenges of Green Computing and its impact and its struggles for the future along with possible solutions.

Keywords: Green Computing, Past, Present, Future, Challenges

I. Introduction

Over the past years, the debate of green technology along with the green computing is increasing day by day and is gone a concerning issue for both governments and businesses [1]. Similar to the security issues, which IT architects were not giving proper attention and eventually they faced the consequences for it. The sustainable environmental design is also going to quickly transform into an unwelcomed architectural issue for modern projects [2]. To be environmentally sustainable is recognized globally as the 21st century important problem [3]. As such more IT stakeholders are moving exponentially towards green IT making the economy green as a whole in return [4] as there also exists studies that proves the fact that the organization, which strived for green computing and achieved it, also have resulted in economic boost [5].

Green computing is where we practice along with studying the lifecycle of computing [6] or studies and practices where computing is achieved to be sustainable environmentally [1]. Green Computing focuses on recyclability of products when they are produced with less hazardous materials and consume less energy during their lifetime [7]. When we want to increase the

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performance of exascale level computing, we face a huge challenge from processors with high-performance as they inhale the power very largely [8]. The information technology systems are based on the following mixtures:

- Networking,
- Hardware, and
- People.

So it compels us to introduce the green computing in a systematic manner where it can become a solution for problems which are increasing regularly [9]. Green computing comes with an objective of continuous improvement in the performance of computing with minimum consumption of energy and carbon footprints. And this is among the main objective of any Green Computing study. Green computing studies deals with manufacturing, using and then efficiently recycling the information technology equipment without leaving any negative impact on the environment [6]. Green Technology is a continuously evolving technology and is not just a limited term for reducing the power consumption in the field of information technology. It even seems impossible for many to understand that what exactly this technology covers?, however it is expected that this will be a field with innovations and changes in daily life within and without information technology. Its development goals focus on following ideas [10]:

- Cradle-to-Cradle – creation of reclaimable and reusable products,
- Sustainability – meeting the present as well as future society requirements,
- Source Reduction – applying production and consumption patterns which shall reduce materials to be wasted,
- Innovation – providing alternatives to health and environment damaging technologies, and
- Viability – forwarding towards viable economy and technology.

This concludes that the green computing is result of the following within the green form [1]:

- Use
- Design
- Disposal, and
- Manufacturing

1.1 Green Concept in other Fields of Studies

When it comes to green technology, the computing or information technology is not the sole-proprietor for it. It is but also widely used in other fields and as a result, we can see in the market products like [11]:

1. Designing Of Hybrid Cars
2. Auto Mobile Manufacturers Are Progressing Towards Manufacturing Of Cars With [12]:
    - Better fuel economy.
    - Lower emission
    - And use of natural materials.
3. Portable Solar Cells,
4. And Even In Projects Of Civil Engineering Such As:
    - Salt Be Gone (making sea water able to use),
    - A Windy Day (Efficient energy generation from Wind Turbine),
    - Rapid Waste Treatment (Sewage treatment),
    - Wave After Wave (Harnessing ocean waves'),
    - Thermal Oceans (Harnessing different ocean water temperatures to generate energy).

1.2 Green Technology Implementation in Cities and Countries

Places like California are having community wide summits to promote green schools and community and are sponsored by Gen 7 as premier sponsor to deliver the green school technology [13]. Gen 7 provides struggles for healthier and greener schools and communities [14].

1.3 Some Other Subject Areas of Green Technology

Some of the other areas where Green Technology is implemented are mentioned below.

- Energy – studies about alternative fuels, and new means of efficient energy generation.
- Environment friendly purchasing – preferring the purchase of products which will cause in lowest environmental impact.

- Green Building – focuses on studies about buildings from its location to choosing its materials.
- Green Chemistry – producing chemicals where hazardous substances' use and generation is eliminated or reduced.
- Green nanotechnology – the implementation of green chemistry and green engineering in manipulation of materials at a scale of one billionth of a meter.

There are a lot more places where this implementation is done, however if we start mentioning those, it will go beyond the scope of this study. The purpose of the study is to review the field of green computing and what have been done by researchers and individuals in past, what is currently undergoing to enhance the technology, and what are the efforts done which may make progress in the field of green technology. The study also mentions few research challenges in field, and discusses few suggestions on how to overcome some of those.

The organization of this study is as follow; Section 1 the current one, gave you the clarification of green computing or green technology concepts along with highlighting few other areas, where green technology is implemented or under research focused. Section 2 is further divided into four parts, first part of which is devoted to introduce the efforts made for technology to become greener or what has be done to adopt lifestyle with technology in a way that they have positive environmental effect. Second part of section 2 is dedicated to the artwork undergoing for greening the computing, and mentions how there are several institutions struggling for educating the professionals and non-professionals about the green computing or green IT implementation in the field of life. Third part of Section 2 predict the future of the green computing by mentioning efforts for the future, hints to protect ourselves from energy loss for future and recommendation to adopt with the future. Finally the fourth part in section 2 of this study discusses challenges which are there for green computing research areas and its implementations. Section 3, is saturated with some ideas and suggestions on how to overcome the challenges. Finally in section 4 Discussion and Future work will be discussed.

II. MATERIAL & METHODS

Following section will explore the past, present and future of green computing.

2.1 Green Computing Past

Without discussing different generations of the computing devices, computer's history remains incomplete. Further the history is equally connected with the struggle for energy efficient computing devices. Each generation of computers has always brought efficiency to the technology usage into the field, such as 486-DX processor that was introduced with support for power management. Alongside, standards for Advanced Configuration & Power Interface (ACPI) with its first version were officially released. These evolutions over time resulted in more productive and at the same time, less energy eaters [15] [16]. There was an age when circuits were known as vacuum tubes, and memory were known as magnetic drums, and computers were huge in size. It was the age when expensive operation was the first click in the mind of one who would think of acquiring a computer. It used high amount of electricity with unbearable heat for even the machine itself as it caused malfunctions due to it [15]. Then with an all-round development of technology and electronic switches were based on transistors and diodes. Latter on the second generation started with faster, cheaper, smaller, and greater efficient to the energy. This caused the computers also to be more reliable [15] [17].

2.1.1 Efforts of Businesses towards Green Technology

Energy Star in 1992 started to make products which would go to sleep when not in use and hence consuming less energy when even they are in standby mode. They also are internationally recognized standard for Energy efficient equipment [7]. Business giants like Dell, IBM etc. have also been struggling for a greener concept of technology usage. Below are some of the business giants outlined for their work in the field. As in year 2009 Dell took first position in Corporate Sustainability Index (CSI) Benchmark Report leaving the 2nd placed firm 52 point behind [12]. Google had been committed to be environment friendly since 2007. They also claim to be using half the power compared to the average consumption of the industry [18]. Google along with Intel in 2007 also initiated the Climate Saver Computing (CSC), a free group was purposed to show that reducing the emissions is beneficial and to promote the smart technologies [19]. IBM controls use and conserving of energy and water through consultation about the same and the implementation of Lean Six Sigma principles. IBM also proved in 1990 to be saving electricity

by around 4.6 billion kWh along with preventing CO2 emission equaling 3 million metric tons of carbon footprints, following cradle – to – cradle and other green technology goals [12].

Microsoft is struggling for the infrastructure design, which is environmentally sustainable. They have a special issue on the topic in the year 2010, they have mentioned a concerning point that the architectural commitment is also necessary alongside the process of bringing efficiency in the IT infrastructure [2]. VMware, in October 6, 2009, for example, announced the opening of a data-center, which is green in its design and build-out. Taking step towards green, VMware with this announcement also started saving $5 million each year and a 70% saving in power. They also employed hydroelectric power, which prevents carbon emission and saves costs [20]. PPM (Processor Power Management) – which efficiently balances system performance with power savings, and ACPI (Advanced Configuration and Power Interface) – which includes updated support for facilities like Core Parking (Core Parking efficiently distribute work load over the dynamically scaled logical processors), is implemented in Windows 7 and Windows Server 2008 R2 by Microsoft. This results in higher energy efficient computers [21]. Yahoo had also made its data centers to be carbon neutral [18].

2.1.2 Professionals' Efforts in The Past

Individual professionals, for example, Mr. Gupta in year 2003 and Mr. Christensen in 2004 did efforts in showing that energy consumption in the Internet issue should not be overlooked. It was since 2008 onwards when the field professionals recognized this and started thinking on the issue with more dedication. Despite the efforts made, these initial efforts were not capable to allow effective IT Infrastructure development which could allow Exascale like computation. The lack of quality approaches and depreciable hardware was also a major hurdle in advancement in this field [16]. Researcher in [22] compiled a report on the America's market in 2008 and mentioned that 25 big companies, were struggling for a greener environment and all these companies are from several different industries, such as auto industry, banking institutions, computers giants, consultants, food, garments and stock exchanges.

2.2 Green Computing Present

There are growing numbers of activists in the market trying to tend towards the green information technology (IT) despite the fact that IT Greenhouse Gas (GHG) Emission share is

2% of the total global GHG emission. For this reason of less emission, the term Green IT is now changing towards Greening by IT. This term means that IT should become a helping hand in reducing the GHG emission globally.

2.2.1 Cloud, Virtualization, and Green

Primary reduction in the energy consumption is shifting towards virtualization [19]. The use of virtualization along with that of Cloud computing is vastly present in our lives and plays an important role regarding green computing concept. And so it will not be fair with the green technology to exclude it from discussing here. Efforts of moving to cloud and using computers or servers of others for your computing requirements rather than purchasing a dedicated machine is considered a greener option in today's era [23]. Similarly there are people shifting towards the virtualization concept whereby they virtualize their several computers or servers on a single physical machine and save their costs along with the energy to an amazingly noticeable amount [24]. The move to cloud computing by Microsoft reduces from 30 to 90 percent per user the energy use and its carbon footprint. Microsoft also facilitates the hardware recycling and donation [26].

2.2.2 Educating the public

Along with the growing literacy in this field, some still do not understand quite well the Green IT term, which includes professionals and users of this field equally. For the said reason to overcome this; the institutions are taking initiative and we see the environment with the pace of the field personals towards certifications and learning about Green IT from different institutions [5]. These institutions include universities like Metropolitan University UK, University of California Santa Barbara, Australian National University, Australian Computer Society, and Linkoping University. Adding to the list are also the training and certification programs from institutions like Global Science and Technology Forum and British Computer Society [25].

2.2.3 Greening the Computing

Present era is the one where no one thinks living without computing devices. While on the other hand the producers are trying to introduce products to use less of the energy with high productivity in return, like making of software to best use the available energy of the hardware

and give results for longer and accurate. The parameters considered for Information Technology to be Green are reduction of waste, efficient usage of energy and its consumption [9]. There has been a considerable dedication of research to understand the implementation of efficiency factor to the environmental impact of the data centers.

Microsoft works with technology partners, government agencies, nonprofits, policymakers and researchers to solve the environmental challenges by understanding, measuring, developing and delivering the IT solutions. For this purpose they are focusing their paradigm shift towards cloud computing.

2.2.4 Work Environment issues

Sitting in front of computer for more than five hours increases the chances to get diseases like [27]:

- Carpal tunnel syndrome and insomnia,
- Depressions,
- Pain in different muscles of the body,
- Headaches,
- Joint pains,
- Eyestrain,
- Stress

Resulting, the employees will be no more productive.

2.3 Green Computing Future

To prevent computing to have any negative effect on humans lives in future, researchers had advised set of goals to follow. These goals are summarized in [18]. Have our digital infrastructure designed optimally so that to reduce the overall energy consumption. Sense the surrounding in a manner to keep you aware of energy consumption around the globe and its effects. While traditional computing systems will be important to execute the models on it for future, we need to predict and react to the upcoming events by responding to the future behaviors by modeling our predictions. Summing up, the researchers suggest using alternatives of our daily works in a digital environment like digitally reading the newspapers on tablets, eliminate

physical disks and use downloaded materials for materials in audio and video formats and online shopping instead of physical onsite shopping etc.

2.3.1 Virtualization and Cloud Computing

By receiving noticeable attention that the cloud computing provides the services and solutions by using the existing infrastructure by having full use of the resources, it is contributing to green computing and is the future of the Green Computing [6]. It is the greenest option to think about other's server when there is need of purchasing your specific server arises [23]. Cloud computing is in concept of virtualization and for the virtualization technologies; companies like VMware are struggling and progressing towards the green concept in the daily computing requirements. Hence the more virtualization and cloud shift paradigms are adopted, more we will follow the green path as it will reduce the energy till up to 80% [24].

2.3.2 Desktops versus Laptops

Individuals use laptops for their day to day work and even for their office work. The companies should be shifting towards the use of laptops instead of desktops for their employees who do not have heavy use from computers. This should be done because the desktop PCs use about six times higher energy than a laptop. This may not seem to be huge saving, but still every drop counts [9].

2.3.3 Dynamic Power Scaling and Smart Standby

Energy can be saved by adopting the smart standby, where by the network or the computing equipment turns itself to a very low energy state but still maintains their network connectivity. Similarly the dynamic power scaling is the concept whereby the device will enter into a low power state whenever there is no transfer of data and will all of sudden go to the full power state when data packets are started transferring through it – this concept adoption will be a greater achievement in the greening of the environment for the computing [28].

2.3.4 Green Networks

The networks of today are increasing heavily and so are their energy consumptions. Due to the consumption requirements, there rises the requirement of large number of devices at every

provider's space. And the providers for the requirement of cutting cost and saving energy, welcomes all the innovations in this field. As the green networking is still at the beginning and is interestingly open issue for the technologists [29].

2.4 Challenges of Green Computing

Computers use a major portion of scarcely available energy to the world [6] [30]. While this era has more need of computing in daily life, therefore this has become the major challenge for the field. This is one of the reasons; that the focus of green computing, is shifting from efficient computing to reducing the IT infrastructure and equipment associated costs as the natural resources are being consumed greatly [7]. For the same purpose major IT companies are focusing in developing machines. While these issues are regularly observed by field specialists, following are still many areas which needs to be focused and some challenges faced [7] [30].

- It is required to control the cooling equipment and other requirements of the data centers which mainly increases the overall power of the IT equipment and is an increasing challenge.
- Equipment for heat removing also requires to be controlled as this is also a major increase in the total power consumption.
- Proper disposing and finding ways to proper recycling of the electronic items also is an issue, which needs to be resolved.
- New Optimization Techniques are needed in Performance-Energy-Temperature aware Computing.

The most important issue of computing is the growing concern about energy conservation in computing activity. It is required to get the maximum benefit by getting a center point in temperature, energy, and performance, by maintaining adequate designing techniques to have a tradeoff among these.

III. RESULTS AND FINDINGS

Society is interested in changing towards the sustainable practices in using energy. And as such communities have introduced incentives for doing so in order to more facilitate the green practices [31]. Researchers are working on the increased issue of reducing the space between power and data centers and the cooling systems [7]. The companies like HP and Dell are trying

to overcome challenges by introducing green computers, like HP rp5700. HP rp5700 PC is expected to have 5 years life at least, have almost all its materials recyclable. Even Dell produces greener computer ever than they were producing 10 years before. IBM in the same way is not behind any one, and is working on a solar cells technology to develop it cheaper and efficient than ever and will be sustainable at the same place [7].

Organizations should adopt ways to find out cooling methods and equipment which consume less energy and provide great cooling, as in this way the cooling costs will be reduced greatly. Also the temperature level of the cooling devices should be maintained in a way that the datacenters will be cool, but the cooling system will not be consuming extra energy. This can also be achieved by building the datacenters on cooler areas, rather than on hot areas, so that there will be less need of cooling devices and energy will be saved.

Organizations and institutions should adopt technology which are built on green concepts, as in such case the computing technologies, will not be producing the heat, and equipment for removing of heat will be less required. There will be a helping hand in the green technology initiative, if the computing devices once purchased are made full use of it, and should be kept using to its maximum life before disposing off or recycling. Also at equipment purchase, the one which can be easily recyclable should be looked for so that there is no worry of disposing the materials. It will be much better if there is agreement set with the seller to provide recycling at the end of life of the equipment.

While it is also the responsibility of organizations and research and educational institutions to provide opportunities and encourage people to work on the field and explore for ways in the green computing or green technology, in order to overcome the challenges of the research areas of the green technology.

IV. DISCUSSION AND FUTURE WORK

Green technology is constantly growing and green computing is becoming crucial part of life, and we learned that information technology is not just an idle observer but is contributing actively in the concepts of green technology or green computing. IT is from its beginning always involved in efforts to reduce the energy consumption and is currently also at a reasonable level along with the progress made by other

fields of studies. Therefore being involved in IT, it becomes the duty of any one, to understand and follow the principles of green computing to be able to be survived in the future. IT industry can adopt different techniques like going for virtualization of servers, moving to cloud, using laptops in place of desktops, even virtualizing the networks and the like. There are the challenges in completely implementing methods where we can get more production out of less energy consumption. There are more areas which still need to be observed deeply by the researchers and we consider it also the responsibilities of institutions to facilitate and encourage the researchers to overcome the exploration of the areas. And the researchers should look into methods to overcome these challenges so that proper implementation of green computing is made possible.

Greening the work environment to bend your computing technology towards green concept, we need to follow some preventions like:

- ✓ Optimizing the environment including the workstation to feel more comfortable for the employees
- ✓ Guide the employees to be in a suitable posture to prevent any physical harm
- ✓ Give your employees frequent breaks from the computers
- ✓ Create such an environment, where employee may sometimes look away from the computer screen; this will prevent eye strain
- ✓ Typing with light touch
- ✓ Avoid strict deadlines on computer related tasks to avoid high stress situations.

Adopting such techniques can lead to improvements in the workers' health and resulting in greater productivity and less energy consumption.

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