

# A Survey of Green Computing for an Energy Initiative

M. R. Sudha<sup>\*</sup>, Komal Aman Singh<sup>a</sup>, A. Saravanakumar<sup>b</sup>

<sup>\*</sup>Assistant Professor, Department of Computer Science, Faculty of Science and Humanities, SRM University, Kattankulathur, Chennai – 603 203, Tamil Nadu, India.

<sup>a</sup>Student, Department of Computer Science, Faculty of Science and Humanities, SRM University, Kattankulathur, Chennai – 603 203, Tamil Nadu, India.

<sup>b</sup>Scientist – R&D Renewable Energy, CHOGEN Powers Private Limited, No 10, Rajagopalan Street, Rajaji Road, West Tambaram, Chennai – 600 045, Tamil Nadu, India

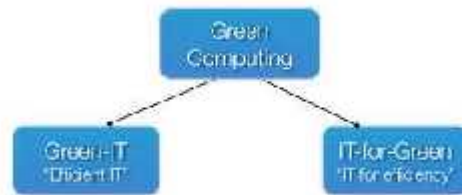
**Abstract:** At present the world of Green Computing is under the consideration of various businesses, organizations and IT industries alike and with the rapid rate of advancement in the field of computers, user demands are higher and this leads to infrastructure development which occurs at a higher rate and resource usage is increasing exponentially. In past few years, computer and IT industries alike have realized the importance of going green, both in terms of environmental issues and minimizing costs, which maximizes the efficiency of a computer, which in turn reduces the increase in resources and this has led to remarkable drift in strategies and policies of various IT industries and organizations alike. The motivation behind this change comes from the ever increasing use computer products in businesses, personal capacity and economical reliance of computers. It is the cost of energy and high usage of resources which is gaining vast awareness and this is one of many reasons behind global warming. This paper presents several green initiatives and a brief understanding and importance of clouds. This way the IT industry as a whole can benefit and in brief, this covers the main research challenges which are still open for debate and will improve the ever growing computer industry requirements. A requirements aim is to develop a solar computer.

**Keywords-** Green computing, Energy efficiency, cloud computing, solar power.

## 1. INTRODUCTION

Green computing is about reducing our carbon footprint and developing efficient ways of using our ever advancing resources in technology, such as the CPU construct, a computers software and hardware and also to maximize energy efficiency during a computers life time. A green computer has many definitions, but this paper focus on the environmental part of it and how we can help in 'Green computing in green initiatives such as power etc and a clouds perspective on helping in green computing. The term green computing came after it was discovered that the development of computers played a pivotal role in carbon emissions and contributed to global warming and destruction of our earth as we know it. Green computing was and is a concept to help improve

computers as a whole and develop a better and more efficient understanding in practices such as the implementation of energy-efficient CPU's, servers and technology advancements as well as reducing resource consumption [1]. San Murugesan [2] notes that this can include designing, manufacturing, using, and disposing of computers, servers, and associated subsystems, such as monitors, printers, storage devices, and networking and communications systems, efficiently and effectively with minimal or no impact on the environment. Regarding clouds, many of us still has a very basic idea on it and it has been stated as the following as currently clouds computing are emerging as a new technique of a massive development being distributed in computing areas such storage and processors. It has changed the computing world as we know it and data is put away from a desktop and is uniquely portable. It can store large quantities of data with the use of an external or internal hard-drive, except you will need an active internet connection and that is still not available all over the world, which is a major disadvantage of using clouds.



**Figure 1: Green computing and its different names**

Green computing is being more environmentally responsible and initializing Eco-friendly use of computers and their resources. It is also defined as the study of designing, manufacturing and engineering of various computing products and also the use of and disposing of computing devices in a way that reduces their environmental impact [1]. Many IT manufacturers and vendors are continuously investing in designing energy efficient computing devices, reducing the use of dangerous materials and encouraging the recyclability of digital devices and paper [3]. Green computing practices came into being in 1992, when the Environmental Protection Agency (EPA) launched the Energy Star program, which was one of the very first concepts of green computing. Various organizations and governments gave importance on Green Computing and this is one of the many reasons it has developed into a necessity in today's world. Green computing is also known as green information technology (green IT). Green computing aims to attain economic viability and improve the way computing devices are used. Green IT practices include the development of environmentally sustainable production practices, energy efficient computers and improved disposal and recycling Procedures. To promote green computing concepts at all possible levels, the following four complementary approaches are employed [4].

**1. Green-use:** Minimizing the electricity consumption of computers and their peripheral devices and using them in an Eco-friendly manner. **2. Green-disposal:** Re-purposing an existing computer or appropriately disposing of, or recycling, unwanted electronic equipment. **3. Green-designing:** Designing energy-efficient, computers, servers, printers, projectors and other digital devices. **4. Green-manufacturing:** Minimizing waste during the manufacturing of computers and other subsystems to reduce the environmental impact of various computing activities. There are various Governments of various

countries actively working to promote green computing concepts by introducing several voluntary programs and regulations for their enforcement and evolution of Green Computing to energize the world via reducing computing environmental impacts. On that point of topic, we discussed about clouds and also the implementation of a green initiatives in Green Computing in which that the role clouds will play in solar computer energy saver as shown in Figure 2.



**Figure 2: Reuse to promote sustainability**

## 2. CLOUD COMPUTING

Cloud Computing is the practice of implementing policies and procedures that improve the efficiency of computing resources in such a way as to reduce the energy consumption and environmental impact of their utilization Figure 3.



**Figure 3: Working Principle of Cloud Computing**

As High Performance Computing (HPC) is becoming popular in commercial and consumer IT applications, it needs the ability to gain rapid and easy access to high-end computing capabilities. This computing infrastructure is provided by Cloud computing by making use of data-centers. It helps the HPC users in an on-demand and payable access to their applications and data, anywhere from a cloud as explained by Nihdi Jain Kansal [1]. Clouds can play a major role in the methodological presentation of solar computers

as clouds can help reduce the power in-take of a computer and the processing reduces the amount of current a computer will use. Clouds have a major contribution to green initiative and also to green computing as this will help reduce material used to make a computer, such as its hardware. A solar panel fitted to a 15 in laptop can generate enough power to last a whole day or maybe two with energy efficient software. Clouds will be storing information on its side such as documents; software etc and this will contribute massively to the generation of power via solar energy. This will reduce production of certain hardware's and improve the world of green computing. Clouds can play a massive role in storing documents or system information such as important documentation reducing the need for an extra external hard-drive and the need for faster CPU's to process more information and the information will be digitally stored on your server built online via the use of the internet. The proposal on the methodology is creating energy efficient solar computers which in the long run will contribute massively in the computing world, with the help of energy software and the reduction on the hardware of a laptop such as power plug point and the reduction of battery size and computer storage of memory (the use of clouds can be used else computer storage will stay the same). There is a Swedish organization called TCO Development launched the TCO Certification program to promote low magnetic and electrical emissions from CRT-based computer displays; this program was later expanded to include criteria on energy usage, ergonomics, and the use of hazardous materials in construction [18]. The remarkable green initiatives are:

**1) Improved Data Center Cooling Methods:**

This is achieved by improving the data center cooling configuration, eliminating considerable amount of energy leaks. It can result in efficient data centers by following leading practices in data center layout and rack and server arrangements. Effective approach include raised floors to improve airflow, moving cooling systems closer to servers to concentrate cold air in the right place, alternating hot and cool server passageway to improve airflow and using water-based air conditioning systems.

**2) Efficient Servers usage:**

Generally, IT companies have been using many server farms or data centers, dedicated to a specific task. These various data servers must be efficiently used. One of the mechanisms is load balancing which chooses the optimum resource among many. Also by using virtual software to perform these tasks, a single server may be used to power these virtual servers, dramatically reducing energy consumption.

**3) Alternative Storage Methods**

Storage drives are another main element of data center infrastructure and, as organizations storage needs increase; more energy is used to power these hard drives. It can be reduced by using large capacity drives and performing data center audits to eliminate redundancies in the system. The alternate storage method is by the use of clouds.

**4) Improving a Printer's Output:**

Centrally locating a printer may be used to handle all printing task, thus eliminating the use of various other printers being left on all day.

**5) Energy saver initiatives:**

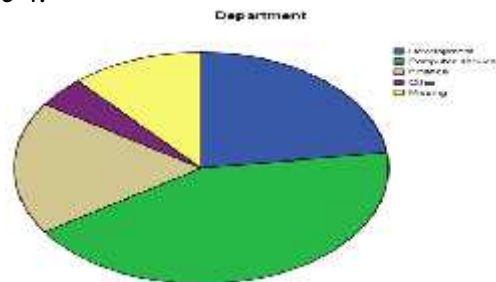
This includes using energy saving settings and encouraging employees to turn off equipment at the end of the work day and on weekends.

## 6) Proper Disposal and Recycling:

This is so important because it potentially eliminates the threat of harmful toxins being released into the environment and allows for the reuse of equipment reducing the amount of waste produced. These initiatives exhibit the requirement of going green, along with above mentioned IT initiatives every sector is practicing a form of green strategy and policies because sustainable development of ICT is the future need [4-5]

## Alternative Sources of Energy

The efficient resource utilization leads towards efficient methods to evolve alternative power sources, which in turn reduces the impact on the environment as development takes place, which includes the consideration of positive and the negative impacts it will have. With time renewable and natural energy sources are being used to power up data centers, server rooms, computer application technology etc. These are a few sources of alternative energy sources, which have little effect on the environment, such as hydro electric power, solar energy and wind power. There are a few computers as seen via the internet are experimenting with renewable energy, but methodology is to include efficiency in the contribution of the enhanced energy received directly by the sun and reduce the hardware on a laptop. We have also discussed about clouds but in very little detail as clouds are already developed such as 'Google Cloud/ Apples famous iCloud. According to apple: Clouds is the next generation improved efficiency of running of many portable devices such as phones and computers. The use of computers in everyday life is shown in the Figure 4.



**Figure 4: Use of Computers in Everyday life**

The table I represent the advantages and disadvantages of renewable energy, while the main focus will be on solar energy: From the below table 1, solar energy has more prospect to it and we discuss about the prospect of computer with solar panels installed into them to generate energy to run a computer with the correct energy saving software. Many are Still in development stages and costly, needs help from software energy saving techniques and the use of clouds to reduce hardware such as storage memory, it will take some time. Wind Renewable, widely available. Some days no wind, will affect generation. Wind is another suitable method with small wind generating turbines on the side of laptops but not useful as you will need wind to generate power and it would not be enough to power or charge a laptops battery. According to research of mines, this is not a viable option nor is it suitable.

Hydro Renewable energy generation is already in function in many parts of the world and it needs large amounts of water to generate any form of power. This is also not suitable for laptops as we need it to be portable and ready to use and the use of hydro electricity is not recommended on a laptop.

Types of energy:	Positives:	Negatives:
Solar	Solar is available widely and can be used as an alternate power source for laptops and computers as it is portable and efficient. Renewable.	Still in development stages and costly.
Wind	Renewable, widely available.	Some days no wind, will affect generation.
Hydro	Renewable, recyclable	Large amount of water needed to generate any form of power.
Wave	Wave energy is a concept in its early stages and has some advantages for cities near seas with rough waves.	Not all countries are near to the ocean and production and maintenance is costly for developing nations.

**Table I: Types of Renewable Energy Sources**

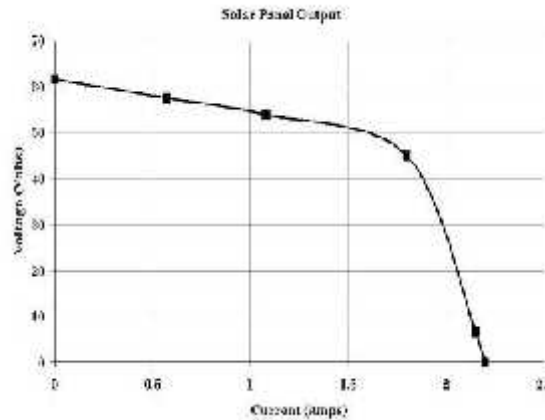
Wave energy is a concept in its early stages of development and surely not suitable for developing an energy efficient computer and has some advantages for cities near seas with rough waves. Not all countries are near to the ocean and production and maintenance is costly for developing nations.

### 3. METHODOLOGY

The implementation of the same type of technology of used on calculators but with more advanced and concentrated solar panels on the side panels of a laptop around the screen. According to various journals, there are already solar powered computers but it's not hundred percent eyes catching nor is it small or powerful enough to power or charge a battery or laptop and those still use a power cable to charge the battery. By implementing the use solar panels about an inch thick around a 15inch screen, basically all around the 15inch screen will have inch thick solar panels. These solar panels have to be concentrated in terms of generating more than enough energy to power up a laptop and at the same time charging its lithium battery. The size of the battery will depend on the operating system and the configurations of certain makes of laptops as not all laptops have the same batteries. This can be achieved by adding more inches of solar panels on the laptop and at the same time making it aesthetic. So development of efficient cores and processors is needed. Extensive research in solar development is needed but it can be achieved as according to experts on solar energy, it can be done and also in the field of implementing solar panels on laptops to improve sustainability via reading more about the ways green computing is trying to improve in all areas to reduce carbon footprint. The implementation proposed methodology is already developed as stated but not fully functional and to make it a desired output for daily use of computers.

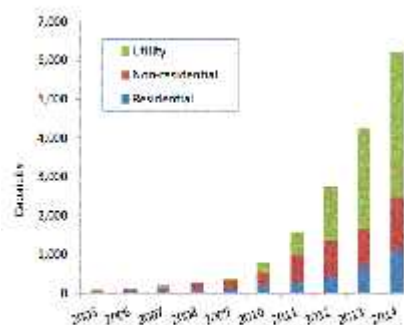
#### 4. RESULTS AND DISCUSSION

The sun is a massive star of burning gases and due to global warming in the sun is reaching our atmosphere faster and hotter resulting in catastrophic consequences. But with this in mind, we can harness the massive FREE energy the sun is giving us and implement it in our technological developments such as the methodology of improving solar panels and energy generating from the sun to power a laptop for more than two days or so. The below figure 5 shows that the difference between a normal, plug in charge laptop and a solar panel charge laptop:



**Figure 5: IV diagram for Solar Panel Output**

The following graph table illustrates the use and power the sun can generate and the power it will have on a laptop containing I3-I7 cores and how much battery consumption it will consume during maximum output. Solar power is renewable throughout the day but at night, it can store its energy via battery with ions developed specially for a laptop battery. The figure 6 depicts the capacity of the suns energy into use by the years and how this will play a major role in development of solar energy on laptops.



**Figure 6: Growth of computers in various fields of solar energy development**

The discussion will be on the fact that the cost of solar technology is high. Since development of an inch solar panels with about 20cm length (depending on the size of a laptop screen) will cost a bit more and but the end product will be satisfactory as we will have reduced energy consumption, efficiency and better quality control on laptops.

LAYER	CATEGORY	UNIT	DESCRIPTION	EXAMPLE
INFR	Productivity	Useful work/W	Green grid data-center performance efficiency(DCPE)	Aims at measuring useful delivered by a data center vs. the power used.
INFR	Efficiency	%	Useful power(for storage, computation, communication)/total	Green grid data center efficiency (DCE)
node	productivity	MFLOPS /W	Number of floating point operation computed per watt	The green 500 list.
App	Power and productivity	Windows and operations	Power used by an application on a node and output is intended as sort records.	Joule-meter is a tool able to estimate instant power consumption of PCs and applications.
OS	Power	Windows	Power used by an OS or an APP on a node	Software is a tool to estimate power used by OS and applications.
HW	Power	Windows	Simple power.	Estimates power consumption on the CPU.

This table II is comparative study of various techniques in Energy measurement [20-24]. The use of solar panels on laptops will reduce about 26% of energy consumption on power grids and thus helping its cause of green computing. Solar powered laptops will be developing at a rapid stage and with the help of international computer companies, solar computing can be a success and an alternative to improving the way we use computers and reducing the causes towards global warming [16-19]

**A few ways that we are already achieving success in green computing is as follows:**

1. Developing computer software to maximize the CPU output.
2. Development of computer hardware that generates more efficiency through better power and battery operations and also by implementing operating systems that are better and more advanced than before to cope with optimizing energy consumption and computer Processes. Green use: Green disposal is one of many ways that green computing is effective as we are trying to reuse an existing computer and or appropriately disposing of it, by recycling it and not just throwing our old computer systems away. Green computing practices include the development of environmentally sustainable production practices, energy efficient computers and improved disposal and recycling procedures. Green computing is already achieving success and continues with the ever improving world of technology [6-11]

**Green computing that is already in use and published [12-15]**

The common man can employ the following general tactics to make their computing usage and to help make it greener by: Use the hibernation or sleep features when away

from a computer for extended periods. Use flat-screen or LCD monitors, instead of conventional cathode ray tube (CRT) monitors.

## 5. CONCLUSION

In this paper, we have surveyed many initiatives on Green computing and on the way it has revolutionized the way of going forward with green computing and modern computers. Green computing is our future computers and will be the driving force of future computing. New computing innovations and applications need to be fulfilled and the green computing requirements for the sustainable development of Information and communication technology will be success in terms of saving the environment. Every research challenge carries a future prospect for employing efficient computing in different areas. We further analyze these challenges for better understanding and in future research of Green Computing. Solar energy will play a major role in the future in almost everything we humans do. A solar powered laptop will help people all around the world and reduce the production of power cables, indirectly helping the cause of green computing and improving efficiency for many processors of a laptop and helping the computer directly improving itself. There are many advantages and very few disadvantages being the fact that it will be costly as solar technology on laptops will require sound functioning with all components of a laptop and much hardware have to be improved to improve efficiency and power outputs or outputs. This is also one of the many reasons that we choose clouds as part of this literature survey to show that all components of an improved solar powered laptop will work together bringing a changed way technology will work. Investigations will continue and have a major impact on solar powered computers and improve in the near future.

## References

- [1] Nidhi Jain Hansal, Priti Dimri, Y. S. Chauhan, "Green Computing Research Challenges: A review International Journal Advanced Research in Computer Science and Software Engineering". International Journal Advanced Research in Computer Science and Software Engineering, Vol. 3. pp. 1075-1077. 2013.
- [2] San Murugesan, Harnessing Green IT: Principles and Practices, IEEE IT Professional, January–February, pp 24-33. 2008.
- [3] [www.technopedia.com/cgreencomputing](http://www.technopedia.com/cgreencomputing). taken from a website that is a software based company and data professionals.
- [4] Kolbasuk McGee, M. "Data Centre Energy Consumption Has Doubled", InformationWeek, p.g 1-5.2000.
- [5] Arnfield, R. Information security goes green. Infosecurity, p. 33-38.2009.
- [6] <http://www.cra.org/ccc/files/docs/init/bigdatawhitepaper.pdf>.
- [7] K. Michael and R. Clarke. "Location and Tracking of Mobile Devices: Überveillance Stalks the Streets", Computer Law & Security Rev., vol. 29, pp. 216-228. 2013.
- [8] <http://www.datacenterknowledge.com/archives/2013/09/17/google-has-spent-21-billion-on-data-centers/>
- [9] Ma Liangli; Chen Yanshen; Sun Yufei; Wu Qingyi, "Virtualization Maturity Reference Model for Green Software," Control Engineering and Communication Technology (ICCECT), pp.573, 576, 7-9. 2012.

- [10] Rodriguez, M.G.; Ortiz Uriarte, L.E.; Yi Jia; Yoshii, K.; Ross, R.; Beckman, P.H., "Wireless sensor network for data-center environmental monitoring," Sensing Technology (ICST), 2011 Fifth International Conference on , vol., no., pp.533,537, Nov. 28 2011-Dec. 1 2011.
- [11] Dustdar, Schahram; Li, Fei; Truong, Hong-Linh; Sehic, Sanjin; Nastic, Stefan; Qanbari, Soheil; Vogler, Michael; Claesens, Markus, "Green software services: From requirements to business models," Green and Sustainable Software (GREENS), 2013 2nd International Workshop on , vol., no., pp.1,7, 20-20 May 2013.
- [12] K. Ashar, "The Next Generation Enterprise: Business as a Service in cloud", LinkedIn.com, pp. 1-2, 2015.
- [13] Dustdar, Schahram; Li, Fei; Truong, Hong-Linh; Sehic, Sanjin; Nastic, Stefan; Qanbari, Soheil; Vogler, Michael; Claesens, Markus, "Green software services: From requirements to business models," Green and Sustainable.
- [14] Software (GREENS), 2013 2nd International Workshop on , vol., no., pp.1,7, 20-20 May 2013 Rodriguez, M.G.; Ortiz Uriarte, L.E.; Yi Jia; Yoshii, K.; Ross, R.; Beckman, P.H., "Wireless sensor network.
- [15] Data-center environmental monitoring," Sensing Technology (ICST), 2011 Fifth International Conference on , vol., no., pp.533,537, Nov. 28 2011-Dec. 1 2011.
- [16] M. Armbrust, A. Fox, R. Griffith, A. D. Joseph, R. Katz, A. Konwinski, G. Lee, D. Patterson, A. Rabkin, I. Stoica, and M. Zaharia, "Above the Clouds: A Berkeley View of Cloud Computing", EECS Department, University of California, Berkeley, Technical Report No., UCB/EECS-2009-28, pages 1-23, February 2009.
- [17] R. W. Lucky, "Cloud computing", IEEE Journal of Spectrum, Vol. 46, pp. 27-45.2009..
- [18] M. D. Dikaiakos, G. Pallis, D. Katsa, P. Mehra, and A. Vakali, "Cloud Computing: Distributed Internet Computing for IT and Scientific Research", IEEE Journal of Internet Computing, Vol. 13, No. 5, September/October 2009, pages 10-13.
- [19] G. Pallis, "Cloud Computing: The New Frontier of Internet.
- [20] T.G. Grid, Green grid Metrics: Describing Datacenter Power Efficiency, 2007.
- [21] A. Kansal, F. Zhao, J. Liu, N. Kothari, A.A. Bhattacharya, Virtual machine power Metering and provisioning, in: Proceedings of the 1st ACM Symposium on Cloud Computing, SoCC'10, ACM, New York, NY, USA, 2010, pp. 39–50.
- [22] S.Rivoire, M.A. Shah, P. Ranganathan, C. Kozyrakis, Joulesort: a balanced energy-efficiency benchmark, in: Proceedings of the 2007 ACM SIGMOD International Conference on Management of Data, SIGMOD'07, ACM, New York, NY, USA, pp.365–376.
- [23] S.Gurumurthi, A. Sivasubramaniam, M.J. Irwin, N. Vijaykrishnan, M. Kandemir, T.Li, L.K. John, Using complete machine simulation for software power estimation: The softwatt approach, International Symposium on High-Performance Computer Architecture (2002) 0141.
- [24] P. Mahadevan, P. Sharma, S. Banerjee, P. Ranganathan, A power benchmarking framework for network devices, in: Proceedings of the 8th International IFIP-TC Networking Conference, NETWORKING'09, Springer-Verlag, Berlin, Heidelberg, 2009, pp.795–808.