

Green Computing and Green Technology based teaching learning and administration in Higher Education Institutions

Shalabh Agarwal¹, KaustuviBasu², Asoke Nath³

Abstract

Green Computing or Green IT refers to the study and practice of using computing resources in an eco-friendly manner in order to tone down its negative impacts on the environment. The major thrust should be to reduce the unnecessary energy consumption, decrease the use of hazardous materials, minimize travel and limit printing so as to have minimum impact on the environment. To implement green computing and green technology, the higher education institutions have a very crucial role to play as these are the hubs for disseminating information and implementing ideas. The concept of Green Computing revolves around making sure that people are practicing how they can save resources when they use the computing technology. In the present paper the authors have made a systematic study on how the educational institutes can save energy, recycle e-waste, to use minimum printed material and to store all information in e-database for future use and modification. To make the environment sustainable the educators, students administrators, guardians have to shake their hands with each other and try to optimize the use of power and more use of e-material rather than printed materials to reduce the carbon foot print. The authors also propose that there should be proper initiative from government sector to introduce green technology and green computing to make this globe sustainable for our future generations.

Keywords

Green computing, Green IT, energy, e-waste, e-database, recycle

1. Introduction

Green Computing is more than just being environmentally responsible. It is also the exercise of

ShalabhAgarwal, Department of Comp. Sc., St. Xavier's College [Autonomous], Kolkata, India.

KaustuviBasu, Department of Comp. Sc., St. Xavier's College [Autonomous], Kolkata, India.

AsokeNath, Department of Comp. Sc., St. Xavier's College [Autonomous], Kolkata, India.

utilizing optimal IT resources in a more efficient way. According to San Murugesan, Green Computing can be described as the process of “designing, manufacturing, using and disposing of computers, servers and associated subsystems-such as monitors, printers, storage devices and networking and communication systems-efficiently and effectively with minimal or no impact on the environment” [11]. The field of Green Computing includes certain policies, procedures and practices that may be used by computer scientists, teachers and IT professionals to optimize the consumption of energy, power and resources and in the process save money and for the most part, preserve the environment. People practicing Green Computing strive to achieve minimum power consumption, optimum use of hardware and software resources, and minimization of generation of harmful gases and wastes while keeping with cost-effective IT solutions. Availing transport to utilize the services provided by such institutions increases environmental pollution as vehicles are one of the highest emitters of greenhouse gases. Many of the technologies we use today consume more energy resources and power than they need to. Using technology causes air and water pollution and consumes renewable and non-renewable resources faster than they can be refilled. Disposal of obsolete computers in the open land disrupts ecology and produces harmful wastes. Needless use of printing uses enormous paper and in turn wastes huge natural resources which are needed to produce the paper. Moreover the chemicals used in ink and ink powders harm the environment in a greater way.

2. Main areas in the IT Sector that have substantial impact on environment

Following are some main areas in the IT sector that harm the environment in one way or the other.

Environment Pollution due to Electricity

Electricity generation is the dominant industrial source of air emissions in the world today. Fossil fuel-fired power plants are responsible for huge sulfur

dioxide emissions, nitrogen oxide emissions, and substantial amount of man-made carbon dioxide emissions. These emissions can lead to smog, acid rain, and haze. In addition, these power plant emissions increase the risk of climate change. However, renewable energy is receiving increased attention by environmental policymakers because renewable energy technologies have significantly lower emissions than traditional power generation technologies. The air emissions impacts of electricity generation vary from technology to technology, as described below.

- **Use of Natural Gas:** At the power plant, the burning of natural gas produces nitrogen oxides and carbon dioxide, but in lower quantities than burning coal or oil. Methane, a primary component of natural gas and a greenhouse gas, can also be emitted into the air when natural gas is not burned completely. Similarly, methane can be emitted as the result of leaks and losses during transportation. Emissions of sulfur dioxide and mercury compounds from burning natural gas are negligible. Compared to the average air emissions from coal-fired generation, natural gas produces half as much carbon dioxide, less than a third as much nitrogen oxides, and one percent as much sulfur oxides at the power plant. In addition, the process of extraction, treatment, and transport of the natural gas to the power plant generates additional emissions.
- **Burning of Coal:** When coal is burned, carbon dioxide, sulfur dioxide, nitrogen oxides, and mercury compounds are released. For that reason, coal-fired boilers are required to have control devices to reduce the amount of emissions that are released. Mining, cleaning, and transporting coal to the power plant generate additional emissions. For example, methane, a potent greenhouse gas that is trapped in the coal, is often vented during these processes to increase safety.
- **Burning of Oil:** Burning oil at power plants produces nitrogen oxides, sulfur dioxide, carbon dioxide, methane, and mercury compounds. The amount of sulfur dioxide and mercury compounds can vary greatly depending on the sulfur and mercury content of the oil that is burned. In addition, oil wells and oil collection equipment are a source of

emissions of methane, a potent greenhouse gas. The large engines that are used in the oil drilling, production, and transportation processes burn natural gas or diesel that also produce emissions.

- **Emission from Nuclear power plants:** Nuclear power plants do not emit carbon dioxide, sulfur dioxide, or nitrogen oxides. However, fossil fuel emissions are associated with the uranium mining and uranium enrichment process as well as the transport of the uranium fuel to the nuclear plant.

Impact of Printing on Environment

Much of our communication and documentation is still conducted via a paper trail. Not only does this leave piles of paper to manage, there's the economic cost of all of that ink and paper and, importantly, there's also an environmental cost involved with printing that we all bear as a society. The environmental impact of printing can be considerable and wide ranging. *In this era of digital documents*, printed books and notes are still the main source of reading. We need to understand that the print industry is one of the most polluting industries in the world.

- The printing industry uses significant amounts of energy. From heating and lighting to powering equipment and final delivery, energy is used at all stages of the print process.
- Large quantities of water are used in most printing processes. In most of the cases, contaminated water is disposed off without cleaning.
- Relatively high levels of waste are generated by the print process. From printing plates and ink tins to pallets and packaging there is plenty of waste produced by the printing industry.
- Many Volatile Organic Compounds (VOC) are believed to emanate from the printing industry. As ink dries, the isopropyl alcohol (IPA), used as a damping solution, evaporates at room temperature, releasing VOCs. VOCs are colourless, odourless gases that are harmful to the surroundings, contributing to global warming and the production of ozone, as well as being hazardous to pressroom workers.
- For inks there are three main areas of concern: **VOCs** – emitted as the ink dries, **Heavy metals** – these are contained in

certain pigments (particularly metallic colours) and can result in environmental and worker health hazards and **non-renewable resources** – the main oils in non-vegetable based inks are petroleum-based.

To make paper, pulpwood trees are cut down in large numbers and are then transported to paper mills where pulpwood fibres are compressed and dried into sheets. This process is extremely energy consuming and contaminated waste waters produced constitute a major environmental hazard. Further, the impacts of deforestation left on the harvested forests which represent a greater cause for concern. Forests remove carbon dioxide from the atmosphere and convert it into carbon via photosynthesis, which is then stored in the wood of trees in a process known as carbon sequestration. As such, trees represent a major natural carbon storage. Their removal reduces the ability of vital processes to take place where atmospheric carbon dioxide is removed and replaced with oxygen. A subsequent increase in the presence of atmospheric carbon dioxide promotes the effect of global warming as carbon dioxide is a major greenhouse gas that absorbs infrared radiation and heats the Earth's surface. A more noticeable impact of deforestation is erosion and leaching brought about by increased surface runoff.

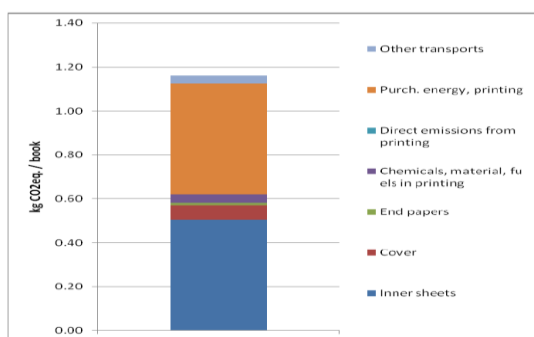


Figure 1: Carbon footprint of a hardcover book (kg CO₂eq/book). [22]

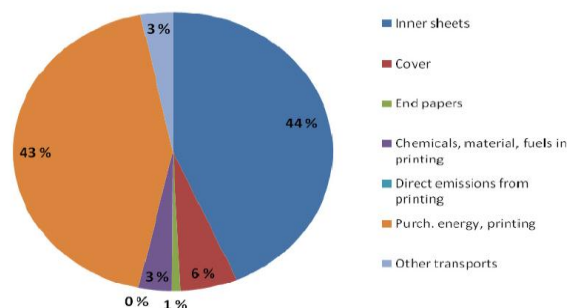


Figure 2: Relative shares of each component of a book in the carbon footprint. [22]

The figures 1 and 2 above give us some idea about the environmental impact of a printed book.

Adverse Effect on Environment due to massive production of E-Waste:

Improper disposal of computers and related equipments, mainly for the electronic waste which affects nearly every system in the human body because they contain an excess of toxic components including Mercury, Lead, Cadmium, Polybrominated Flame Retardants, Barium and Lithium. Even the plastic casings of electronics products contain Polyvinyl Chloride. The health effects of these toxins on humans include birth defects, brain, heart, liver, kidney and skeletal system damage. They will also significantly affect the nervous and reproductive systems of the human body. All these toxins are create environmental and health risks when computers are incinerated, put in landfills or melted down. When computers monitors and other electronics are burned they create cancer-producing dioxins which are released into the air we breathe. If electronics are thrown in landfills, these toxins may leach into groundwater affecting our local community. The figure below gives us some idea about the danger of e-waste. Most of the toxic components shown in the figure-3 ends up in landfill, poisoning soil and water.

Table 1: E-waste toxic components and health hazards[19]

Toxic Materials	Birth Defects	Brain Damage	Heart, Liver & Lung Damage	Kidney Damage	Nervous / Reproductive System	Skeletal System
Barium		Yes	Yes			
Cadmium	Yes			Yes	Yes	Yes
Lead	Yes	Yes		Yes	Yes	

Lithium	Yes	Yes	Yes	Yes	Yes
Mercury	Yes	Yes	Yes	Yes	
Nickel	Yes		Yes	Yes	Yes
Palladium	Yes	Yes	Yes	Yes	
Rhodium			Yes		
Silver	Yes	Yes	Yes	Yes	Yes

Pollution of Environment due to emissions from Vehicle

The emissions from vehicle may further affect the environment in several ways. Cars emit greenhouse gasses, such as carbon dioxide, which contribute to global warming. Some air pollutants and particulate matter from cars can be deposited on soil and surface waters where they enter the food chain; these substances can affect the reproductive, respiratory, immune and neurological systems of humans and animals. Nitrogen oxides and sulfur oxides are major contributors to acid rain, which changes the pH of waterways and soils and can harm the organisms that rely on these resources.

Vehicles contain many different fluids, including motor oil, antifreeze, gasoline, air-conditioning refrigerants, and brake, transmission, hydraulic and windshield-wiper fluids. In most cases, these fluids are toxic to humans and animals, and can pollute waterways if they leak from a vehicle or are disposed of incorrectly. Many vehicle fluids are exposed to heat and oxygen while an engine is running, and undergo chemical changes. These fluids also pick up heavy metals from engine wear and tear, making them even more toxic to the environment.

Emissions from cars increase the levels of carbon dioxide (CO₂) and other greenhouse gases in the atmosphere. At normal levels, greenhouse gases keep some of the sun's heat in the atmosphere and help warm the Earth. That said, many scientists believe that burning fossil fuels such as gasoline causes greenhouse gas levels to spike, leading to global warming.

Although the U.S. Environmental Protection Agency (EPA) declared cars "mobile sources" of pollution, they aren't the only culprits. According to the EPA, motor vehicles collectively cause 75 percent of carbon monoxide pollution in the U.S. The Environmental Defense Fund (EDF) estimates that on-road vehicles cause one-third of the air pollution that produces smog in the U.S., and transportation

causes 27 percent of greenhouse gas emissions. The U.S. has 30 percent of the world's automobiles, yet it contributes about half of the world's emissions from cars. From the above we can conclude that the major reasons for pollution and thus endanger the environment are:

1. Electricity
2. Printing
3. E-waste
4. Vehicle emissions

So therefore, Green Computing or Green IT is the area of study which tries to find out ways and means to limit the use of these activities in order to reduce their impact on the environment.

3. Some important measures/steps may be taken by the academic institutes to practice real green computing

Over the years, Green Computing has been an area of interest and various research activities have been carried out to implement Green Computing in educational and IT institutions. The following steps will show how Green Computing can be achieved and implemented successfully in an Educational Institution. Individual users at IHEs can adopt simple ways to cut down on the consumption of energy and power resources.

Green Computing in Teaching and Learning:

Online learning also known as E-learning refers to the use of various electronic media and information and communication technology in education. E-learning delivers education through various kinds of media such as audio, video, animation and images [2]. It replaces traditional printed books and introduces e-books with e-mail based instructions, CD-ROMS which saves a lot of printed stationeries. Online learning also reduces the need for campus utilities — with fewer classrooms used, less heating, air conditioning, and lighting are needed. In addition, traditional face-to-face classrooms tend to use a lot of

paper for such things as handouts and course assignments [3]. Online learning facilitates face-to-face communication through video-conferencing, bulletin boards, chat rooms and forums. As a result, students do not have to drive to their institutions thus cutting down on pollution due to travel. Desktop web (or video) conferencing can reduce the travel needed for student office visits, staff and faculty meetings, and class sessions. Web conferencing applications allow instructors to teach face-to-face classes with audio and video to and from off campus locations. Also, users can employ web conferencing to conduct face-to-face meetings from desktop or laptop computers with people at remote locations [3]. Whereas much of the existing online learning today occurs in asynchronous classes, desktop web or videoconferencing provides opportunities for instructors to teach live, synchronous classes via the Internet [3]. With the introduction of relatively low cost and high speed broadband services video-conferencing has made progress in education. This facility brings people together by reducing the need to travel thus reducing carbon emissions and global warming [6].

Also another commonly used E-learning practice is the exchange of E-mails. Students can e-mail their instructors for assignments and other electronic documents. E-mail is considered "green" as it helps to reduce carbon footprints by eliminating the need to print when used to hand out documents electronically.

Implementing Green Computing in Management, Administration and to disseminate Information in a College:

- **Online admission tests and publication of results:** The educational institution can save huge amount of printed/blank stationery by designing efficient software to organize online admission tests for the selection of applicants. The institutions at the same time may publish exam results in their college website itself to save the college staff from using too many resources to publish the results of thousands of students.
- **Evaluation of exams through software:** Development of software to evaluate exams also promotes Green Computing by saving resources. Marks obtained from the online evaluation can be fed directly into the students' database eliminating the need to use natural resources. Electronic evaluation

systems have replaced the traditional paper evaluation forms in many institutions thus saving the need for using paper and hence promoting Green Computing.

- **Submission of marks, attendance, payment and other details through software:** The administrative staff may enter student records, their opted course, number of periods attended, marks obtained, credits earned and fees payment and due details through a software system that is easy to operate and also saves the overhead of keeping track of changes in the records and at the same time saves the cost of using natural resources. The staff is saved from generating manual reports on a student's performance thus saving the need for extensive use of energy and paper. Generation of failed and arrear candidate lists becomes easier as the software takes care of aggregate calculations. Designing simple yet highly effective software enable students as well as the administrative staff who are not tech savvy to easily enter records and obtain consolidated mark sheets, examine discrepancies in attendance and marks and directly calculate totals and percentages without having to do them manually in pen and paper.
- **Introduction to College/academic institute through Online Brochures:** Information about the educational institution can be given through their Website in an online brochure which saves paper and hence conserves the environment. It also saves fuel, thus conserving power and energy resources, as the students may simply access the college website at home to obtain useful information instead of availing transport and burning fuels thus reducing carbon footprints.
- **Online filling and submission of applications and feedback:** It is one of the most common ways of implementing Green Computing and has been adopted in various IHEs around the world. Most Green Computing solutions in an institution aims at saving paper, fuel, power and other energy resources and this method is one of them. Online filling of application forms and feedback forms has become the most preferred and eco-friendly way of submitting students' records and many

institutions have come up with highly developed and efficient software to achieve the same. Online application has the benefit of saving time required in transit and also adding to the preservation of the environment by reducing carbon footprints.

- **Course details and associated staff members:** The administrative department can keep track of the courses offered in the institution and the teachers and staff associated with each through easily maintainable and energy efficient soft copies published online. It helps users, whether students, staff or teachers to easily keep track of changes in the departments also saving the need for maintaining physical records in paper. Also the management staff in association with professors can plan new curriculums and modify existing courses and publish them online for better access by the students. It saves a lot of paper and printing, thus provides environment friendly solutions.
- **Online management of college events:** Several software are available which help the synchronization and planning of college events which are both eco-friendly and easy to operate. Also, online graphical invitations to guests can be made which are attractive, cost efficient and achieves environment conservation all at the same time.
- **To maintain Management and administrative data through on-line:** The administration being at the highest level of an institution hierarchy is most importantly involved in managing the synchronization of activities, records and information among various departments within the college. Earlier such synchronization was achieved through peons carrying large registers from one department to another for the purpose of updating and modifying. This called for increased the levels of paper waste thus damaging the environment. Green Computing facilitates the maintenance of teacher and staff records without using paper thus achieving environmental conservation and cost-effectiveness at the same time. Teacher and staffs can use software to apply for leaves and obtain details of their salary and payments through such software and update and modify them at the same time. Efficient databases used by the

administration to develop the software reduce inconsistency and incorrectness of data. Designing data handling software incurs heavy initial cost. However in the long run, software being easily maintainable compensate for this cost and provide energy efficient methods for handling large amounts of data. Most institutions have resorted to such Green Computing practices as these to find solutions to the increasing environmental pollution problems.

- **Online fees payment system:** The college staff can be saved from using manual methods for fees payment by developing systems that feed a student's payment details directly into the database without involving any paperwork. This eliminates the need for printing large volume of payment slips and additional hard copy documents as the administration can easily generate due and pending payment lists through the software. This practice has the additional advantage of providing security by eliminating the need for standing in long queues and putting large sums of cash at stake. It also makes maintenance of payments records easier to achieve.

Green Computing by reducing e-waste

Product longevity plays an important role in sustainability because the longer a product is in use, the fewer the numbers of that particular product that need to be created as well as disposed of. We have the tendency to always get the latest device whether or not it is actually needed. In the process we often replace a computer which may be adequately efficient for the time being. It is important that computers and other devices are appropriate for the work that they are intended to support. Faster computers, more memory, and larger monitors are not always necessary. The IT department should judiciously weigh the requirements of the departments before going in for new equipment. If something goes wrong with a computer or related device, often only one component is actually broken, not the whole thing. Check out with the maintenance service providers and get the equipment repaired instead of rejecting it completely. Moreover, consider upgrading and replacing individual components instead of the entire thing. In case the equipment cannot be upgraded to satisfy your needs, consider reselling or donating in place of throwing it. All these

practices will help reduce e-waste and in turn save the environment.

Green Computing by saving electricity

Computers consume a substantial amount of electricity in an institution as almost all the activities within the campus use Information Technology in one way or the other. It is important to save energy within the campus for reasons of cost and environment. One way is to buy ENERGY STAR label computer equipment's to save electricity and protect the environment through energy efficient products and practices. In addition to immediate costs, purchasing decisions have longer term implications. For example, a 19" monitor uses nearly double power than a 17" monitor. Consider purchasing an environmentally friendly laptop that uses about 1/4th of the energy of a desktop computer. Replace a CRT monitor with an LCD monitor. LCD monitors can use 1/2 to 3/5 the energy of a CRT monitor. Turn off your computer when you will not be using it for several hours to save a lot of electricity. A computer also releases CO₂ while it is kept on. Wasted energy and increased pollution make turning off computer when not in use is an easy way to reduce the institution's environmental footprint. Enable power management features on your computer. Avoid phantom power from connected devices. When plugged in, a computer and other electronic devices still consume energy. You could save as much as 10% of energy simply by unplugging such devices when they are not being used. To make this easier, buy a power strip, and plug your computer and its peripherals into that power strip, and shut off the strip when you are not using your computer.

4. Green Computing practice in Some Educational Institutions

University of Michigan

The University of Michigan has an award-winning history of sustainability initiatives, including research and student activism as well as campus facilities-related efforts [15]. Green Computing Practices in this University include alternative transportation, energy audits, and improvements to buildings, green purchasing, using renewable resources and employing recycling systems. Before 2007, however, information technology (IT) had largely been ignored, until Google founder and Michigan alumnus Larry Page invited the university to become a founding member of the Climate Savers Computing Initiative (CSCI) [15].

Harvard University

Harvard University has the FAS Energy Reduction Program which encourages Energy Conservation across all departments [3].

University of Ohio

The University of Ohio uses a Computer Management System that shuts down computers when not in use. . It has saved the university 15,150,000 kilowatt hours and 15,000 tons of CO₂, which makes up 45% of their total computer energy use [17].

Carnegie Mellon University

Carnegie Mellon University (PA) participates in EPA's Energy Star Computer Monitor Power Management Program: "Sleep is Good!," which sets their computers to sleep/standby mode [17].

Pomona College

Pomona College (CA) was able to save approximately \$66 per school-owned computer, while reducing GHG emissions by nearly half a ton of CO₂ per year per computer

University of Florida

The University of Florida has replaced 3,700 incandescent light bulbs in university-owned light fixtures with compact fluorescent bulbs in the 208 apartments, which they anticipate will save residents more than \$15,000, and will eliminate 200 tons of CO₂ annually [17].

Yale University

The Office of Sustainability at Yale University promotes power management and the purchase of Energy Star rated products [3]. These Offices are situated at different sites on the campus and carry out research driven facilities to practice Green IT.

5. Conclusion and Future Scope

Computers and related technologies are used in every department on an institution campus. In order to achieve the mission of the campus without causing further harm to our environment and the community, we must be smarter about the technology tools we choose and how we use them. This requires for all of us to understand the possible negative impacts of the tools we use, that we understand how we can reduce or avoid those impacts, and, most important, that we take action in implement sustainable efforts in practice. Presently, with a greater concern for the environment, Green Computing is well practiced in most institutions and has contributed substantially to reducing carbon emissions and conserving the environment. However, a greater and sincere effort is required by one and all in an institution to realize the

concept of Green Computing in actual practice. Staff, teachers and students can start making small contributions towards sustainability implementing the concepts and guidelines discussed in this paper. Such small contribution can lead to a substantial increase in energy efficient and environment friendly institutional structures, and also bring down the levels of carbon emission and waste generation.

Green Computing is a long term commitment that requires widespread awareness and appropriate planning to implement the concepts. The greatest challenge is to swell the responsiveness towards green computing and make the personnel in the institutional management realize the long term benefits of Green Computing, both in terms of economy and sustainability. The dream of a environment friendly, technology enabled campus can be realized with the collaborative efforts of all in the institutions. Although there is a debate on the perception that computers are both a part of the problem as well as a part of the solution, it will be too late before a conclusion is drawn on this issue. In our view, the practice of Green Computing must be immediately incorporated in all institutions. Institutions, being the centre of learning and guidance, must advocate this concept by example and not by hypothesis.

Acknowledgment

We are very much grateful to Department of Computer Science of St. Xavier's College to give opportunity to prepare this paper. We sincerely express our gratitude to Fr. Dr. Felix Raj and Prof. B. D" Silva for constant support and. SA and AN are also grateful to the UGC, India for granting a MRP on Green Computing.

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Prof. Shalabh Agarwal is the Head of the Depart. of Comp.Sc., St. Xavier's College (Autonomous), Kolkata. Keeping up with the latest trends, he is very keen on research and has many publications in International and National journals, including a few in IEEE sponsored conferences and journals. His main area of research is Green Computing, Sustainable IT infrastructure and Cyber Law.



Dr. Asoke Nath is Associate Professor in Department of Computer Science, St. Xavier's College (Autonomous), Kolkata-16. His major research areas are Cryptography and network security, Data hiding, Image processing, Green computing, E-learning.



Kustuvi Basu is a student of B.Sc. Computer Science (Honours) at St. Xavier's College (Autonomous), Kolkata. She has immense interest in research and has contributed considerably in research endeavors.