Trends and Awareness in Green Computing Initiatives: a Comprehensive Study

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Abstract: During recent years, attention in 'Green Computing' has moved the research into energy-saving techniques for home computers to enterprise systems' Client and Server machines. Saving energy or reduction of carbon footprints is one of the aspects of Green Computing. The research in the direction of Green Computing is more than just saving energy and reducing carbon foot prints. In the present paper the authors have made a through study on different issues of green computing in all spheres of the society. An online survey was made on green computing initiatives across the globe and the feedback analyzed and interesting results came out. A further research is necessary to explore green ICT initiatives among common people. The authors also tried to explore the current trends and challenges in green computing and also what will be future trends in green computing.

Keywords: Green Computing, online survey, Green ICT, Client and Server machines, carbon foot print.

I. INTRODUCTION

Green computing refers to eco friendly and environmentally responsible use of computers and related technologies such as monitors, printers, storage devices, networking devices and so on. It is the study and practice of designing, manufacturing, using and disposing of computing devices in such a way that reduces their negative impacts on the environment. Developing energy efficient computing devices, reducing energy wastage due to irresponsible usage patterns, encouraging recyclability of devices and paper and preventing frequent disposal of devices by promoting recyclability are all a part of green computing technologies. Green computing aims to use computers with minimal energy and natural resource wastage by ensuring least human impact on the environment. With the increasing recognition that human activities have a major contribution to global warming, green computing practices are adopted for tackling the environment issues that computing devices have on the environment. Such practices are an economic and environmental imperative, as well as a part of every citizen's duty towards environmental sustainability. The concerns due to modern technology are varied and diverse. Each and every part of the devices we use have some impact on the environment. The power used to run a device is generated by burning fossil fuels which have a high amount of carbon footprint. The fossil fuels are non renewable sources of energy which are very limited in quantity and are depleting very rapidly. Electricity generation from fossil fuels have many detrimental effects on the environment. The emissions from the burning of fossil fuels contain carbon dioxide, carbon monoxide and other green house gases and are of serious concern. They not only pollute the atmosphere but also have serious health impacts. They are also the reason behind greenhouse effect and global warming. Worldwide emissions of CO_2 from burning fossil fuels total about 28 billion tonnes per year. About 38% of this is from coal and about 43% from oil. Every 1000 MW power station running on black coal produces CO_2 emissions of about 7 million tonnes per year. If brown coal is used, the amount is about 9 million tonnes. After lighting,

computers and monitors have the highest energy consumption in office environments. Studies have shown that power management of computers and monitors can significantly reduce their energy consumption, saving hundreds or thousands of dollars a year on electricity costs. The average computer requires between 36W and 250W when it is active, and between 1W and 27W in low power mode. Monitors, like computers, vary in the amount of energy they require. The average CRT monitor requires between 66W and 135W when active, between 0W and 19W in low power mode, and between 0W and 5W when switched off. Technotrash, also called electronic waste or e-waste, is any broken or unwanted electrical or electronic device, and is currently the most rapidly-growing type of waste. Technotrash that are thrown away with the regular trash usually ends up in a landfill. Most electronics contain non-biodegradable materials, and heavy metals and toxic materials like cadmium, lead and mercury. Over time, these toxic materials can leak into the ground, where they can contaminate the water we drink, the plants we eat and the animals that live around the area. Many European countries have even banned technotrash from landfills. These toxic materials can cause all kinds of bad effects including nausea, diarrhea, vomiting and even cancer. If you keep eating and drinking contaminated food and water, these toxins can build up in your body. If you eat animals that have been contaminated, you're getting a double dose of toxins. What's even worse, your body can't properly process some of these metals and so they might take years to get out of your system. According to StEP, an initiative that advocates reduction and proper treatment of electronic waste, a record amount of 48.9 million metric tons of e-waste was generated worldwide in 2012. Every day a vast number of electrical and electronic devices end up as waste; some of them ready for scrap, others just obsolete. All this is gradually mounting up to a serious environmental problem that needs to be addressed.

II. IMPLEMENTATION OF GREEN COMPUTING

The negative effect of computer use already been discussed in introduction section. So therefore, it now mandatory to find way out how to reduce the negative effects of using computers in individual level and also in Institutional level. One has to find effective and eco-friendly means that will help to reduce the adverse impacts that modern technology is causing to the world. Green computing is hence a solution to this problem. The steps that can be taken to implement green computing are as follows :

2.1 Desktop virtualization: It involves running two or more logical computer on just on one set of physical hardware. This not only saves the cost of multiple computers, but also reduces carbon footprint due to the manufacture and usage of multiple computer devices. In virtualization, one physical server hosts multiple virtual servers. Virtualization enables data centers to strengthen their physical server infrastructure by hosting multiple virtual servers on a smaller number of more powerful servers, using less electricity and simplifying the data center. Besides getting much better hardware usage, virtualization reduces data center floor space, makes better use of computing power, and greatly reduces the data center's energy demands.

2.2 Power management: Power management is a way of ensuring computers and monitors are turned off when not required and in low power mode during idle periods. Manual power management, which relies on education of users to turn off their computers, can achieve impressive results with ongoing education and reinforcement. Alternatively, automatic power management relies on software, or built in energy saving features. Theoretically, automatic power management can achieve 100% power management, with all computers turned off when not required and in low power mode when idle. Energy star label indicates the energy efficiency of the appliance such as TV, which goes between one and ten stars. The greater the number of stars the higher the efficiency. So we can *go green* by purchasing an appliance on the basis of energy star. Also we should use our devices in a manner that they require less cooling hence reducing energy requirements.

2.3 Displays and computer devices: LCD monitors require much less energy than CRT monitors. LCD monitors require a fraction of the energy of CRT monitors. The average LCD monitor requires 15W when active, 1.5W in low power mode, and 0.5W when turned off. Laptop computers consume a fraction of the energy of desktop computers. This is due to a number of factors such as :

(i) They draw less power.

(ii) They go into low power mode more quickly than desktop computer to preserve battery power.

(iii) They are more frequently turned off and unplugged than desktop computers.

On average laptop computers spend more time turned off and in low power mode than desktop computers.

2.4 Basic Computer Ethics: People should be informed and educated about the basic ethics that should be followed while using a computer device. These include:

(i) Enabling PC power management feature in the operating system.

(ii) Turning off computer when not in use.

(iii) Screen saver doesn't save energy. So one should avoid using screen saver and better turn off the monitor.

(iv) PC should be in sleep mode it is not used by anyone.

(v) Always use the 80 plus certified power supply units for our computer.

2.5 E-Waste Recycling – E-waste recycling is the reuse or recycling of e-waste such as old computers, monitors etc. Instead of throwing it we should try contributing it to the non-profits and charities or submit it to the municipal or private recycling bodies. By using the hardware for a longer period of time, the total environmental footprint caused by computer manufacturing and disposal will be reduced greatly. We can also refurbish old computers and servers to meet new requirements instead of purchasing new devices. Printer cartridges can also be recycled. Instead of disposing them off and increasing the e-waste burden, we can refill them and use them again.

2.6 Telecommunication – It is a work arrangement in which people work from home, making use of the internet, telephone and email. The terms teleconferencing, telework or telepresence are often used interchangeably and are used as a method to implement green computing. These technologies offer many advantages such as reduction of greenhouse gas emissions related to travel, more work satisfaction and lower costs for office space, heat and lighting.

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III. RESULTS AND DISCUSSION

An online survey was conducted through the website www.greenict.in/greensurvey/ to understand the awareness towards Green Computing and to understand the computer usage behaviour of occasional users, experts and professionals. The questionnaire consists of 25 questions upon the profession, computer/ electronic device usage details of users, their awareness about the effects on environment and their knowledge of green computing practices. Based upon the feedback of about 1000 people, the authors have selected some questions relevant to the present study and carried out a discussion about the trending ways and how to deal with it for a better and greener and cleaner future.

Table-1: Use of computer in daily basis

Question : How many hours per day do you usually use the computer ?				
	Option-1	Option-2	Option-3	Option-4
Options→	Less than 1 hour	1 to 5 hours	5 to 10 hours	More than 10 hours
Number of persons	147	675	156	42
Percentage	14%	66%	15%	4%

Hours per day computer used
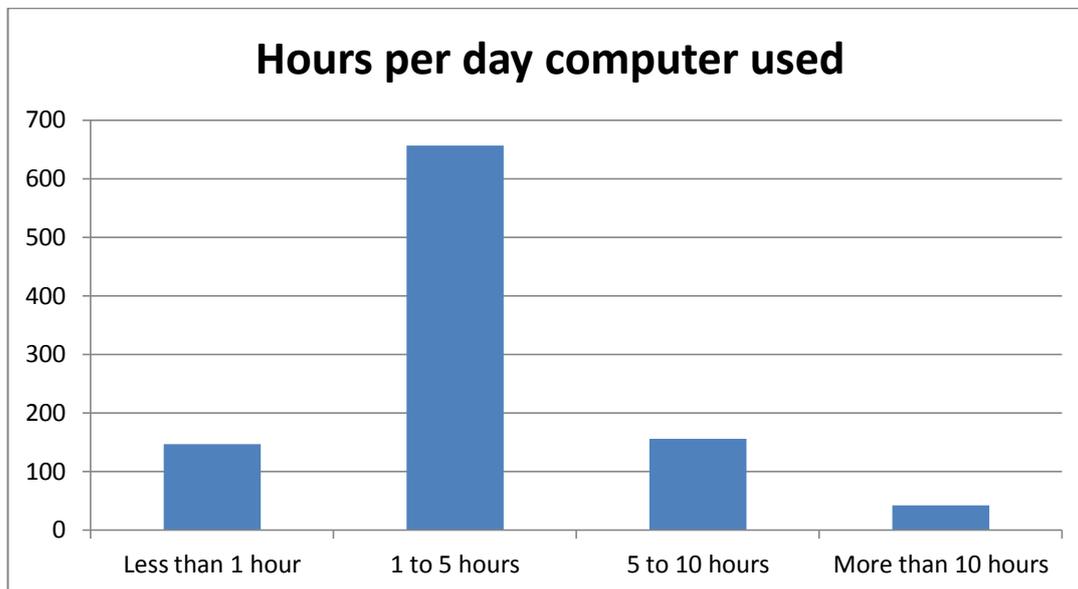
The survey shows that a majority of the people use computers for a period of one to five hours daily. Out of the 1002 people conducting the survey, 657 people, i.e. almost 66% use computers/laptops for around 1-5 hours daily. So it is recommended that certain power optimization and saving techniques be implemented which accounts for less power consumption when users use computer devices for a period of one to five hours. Also, about 15% of the surveying people use computers for a period of 5-10 hours whereas 14% use computers for less than an hour. While this survey is carried out with just 1002 surveyors, it does depict the picture of computer usage of the entire masses. With majority of the people using computers for more than 2 hours, it is extremely important that people be informed about power saving techniques present in their devices when using it for long periods in order to reduce electricity consumption. This reduction in consumption of electricity would collectively reduce the energy usage to a great extent thereby reducing the carbon footprint and other effects caused during the generation of power.

Table-2: Number of computers owned by individuals

| Question : How many Computers/laptops have you owned in total?				
	Option-1	Option-2	Option-3	Option-4
Options→	1 computer	2 computers	3 computers	More than 3 computers
Number of persons	426	306	150	123
Percentage	42%	30%	15%	12%

Number of computers/laptops owned
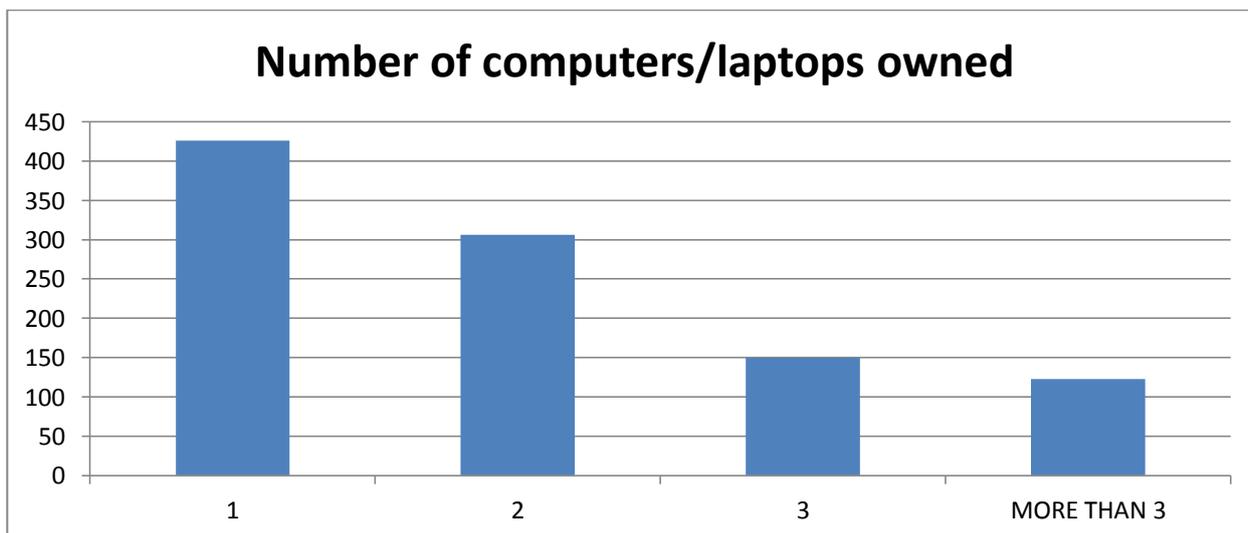
The survey shows that a majority of the people, about 42%, own only one laptop/computer although a hefty amount of people, about 30%, use two computer devices. About 28% use three or more than three devices. This clearly shows that people change laptops very often which can be for two reasons

i)   Less Durable laptops which stop working frequently.

ii)   Changing needs of people forcing them to buy laptops with better specifications,

So it is important that computer devices be made in such a way that they are durable and long lasting. People should be informed about the amount of energy required in manufacturing one computer device and what effects it has. Moreover, for every device discarded, e-waste is generated which in turn adds to the global pollution and increases the carbon footprint. More number of devices discarded would mean more e-waste generated. It is extremely necessary that people be informed about these factors so that it will help in reducing the amount of e-waste generated since reduction in the number of devices owned by users would mean less number of devices being manufactured and less carbon footprint.

Table-3: Average quantity of papers printed per day

Question: What is the average number of pages printed per day?			
Options→	Less than 10	11 to 60	51 to 100
Number of persons	894	60	48
Percentage	89%	6%	5%
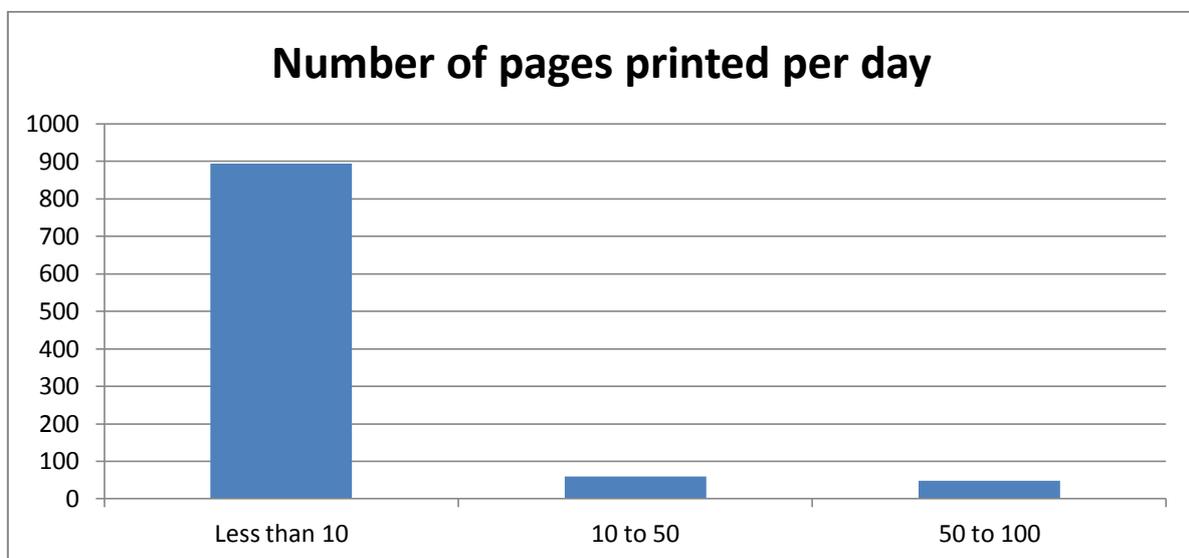
This survey shows that a majority of users, about 89%, print an average of less than 10 pages per day, with some users, about 6%, printing between 10-50 pages and some, about 5%, between 50-100 pages. There are users who print more than 50-100 pages a day so it is of utmost important that certain ink optimization techniques are introduced. This will help reduce the amount of ink used to print a page, so that overalls no of cartridges used are less, thereby reducing e-waste and saving resources. The ill effects of inks used in cartridges are well known. Potential health effects of chemicals used in printing include:

1)   Solvents and inks can irritate the skin leading to dermatitis

2)   Some products can cause skin allergy and asthma (e.g. UV inks, laminating adhesives)

3)   Some solvent vapors can make you dizzy, drowsy and affect your central nervous system

4)   Some solvents can damage internal organs (e.g. liver /kidney) if exposure is over a long period

5)   Corrosive acids and alkalis can cause skin burns and eye damage (e.g. plate developers)

6) Some inks cured by UV can cause cancer and harm to the unborn child (Products supplied in Europe by members of the British Coatings Federation (BCF) and/or European Printing Ink Association (EuPIA) should not fall into this category)

Ink cartridges in landfills can take up to a millennium to decompose, as they contain resin. Toner cartridges contain toxic ingredients such as volatile organic compounds in the form of solvents. It takes almost a gallon of oil to make a single laser ink cartridge. Manufacturing a single toner cartridge releases 4.8 Kilograms of carbon dioxide into the atmosphere Printers should be introduced that reduce the electricity consumption when used for long periods of time so that more pages can be printed using less electricity, thereby reducing the amount of carbon footprint.

Another environmental impact of printing is the wastage of paper. Papers are used for printing in all homes and offices. But a majority of this printed paper ends up as garbage in landfills. Manufacturing every paper depletes various resources. 324 liters of water is used to make 1 kilogram of paper. 10 liters of water is needed to make one piece of A4 paper. More importantly deforestation is a growing concern and 93% of the paper we use comes from trees. 50% of the waste of businesses is composed of paper. When paper rots, it emits methane gas which is 25 times more toxic than CO2. Hence, we should efficiently use papers for printing. We should try using both sides of the paper while printing and also use font size reduction features so as to accommodate maximum printing content in a single page. We should also recycle paper and resort to using soft copies instead of hard copies.

Table-4: Use of computer in low power consumption mode

Question: Do you switch your computer to low-power consumption mode every time?			
	Option-1	Option-2	Option-3
Options→	Unaware of such modes	Sometimes when necessary	Always
Number of persons	225	582	195
Percentage	22%	58%	19%
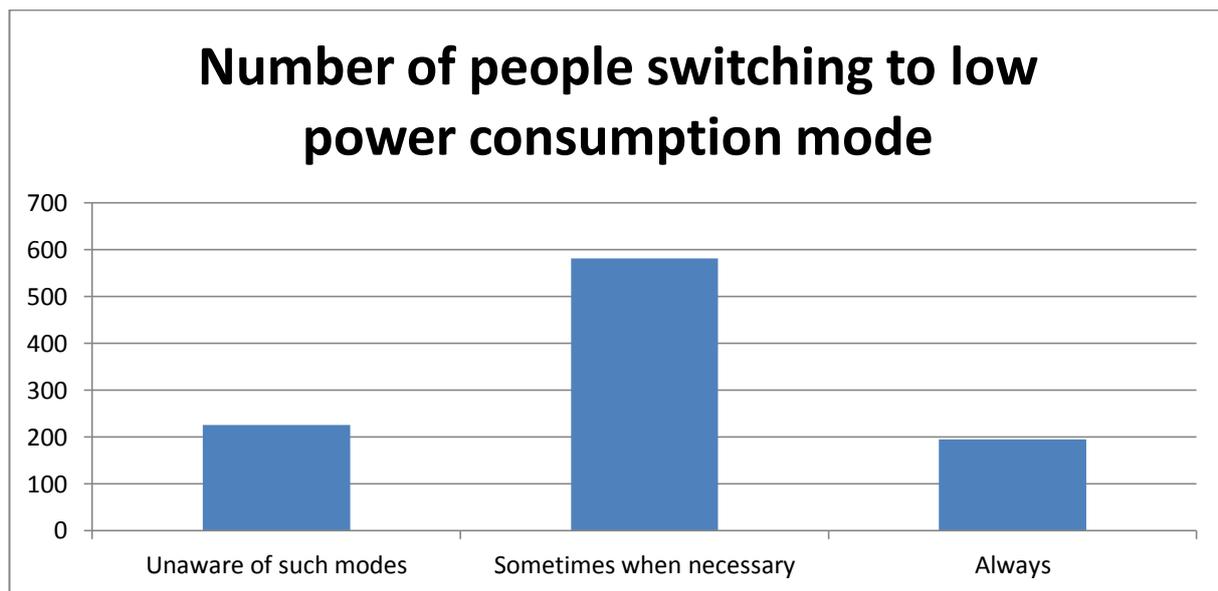
This survey shows that there are more number of users who have no idea about low power consumption modes present in computers than the number of users who always switch on low power consumption. This survey shows the reflection of the general masses, informing that about 22% of the general public have no idea about low power consumption modes. So it is of great importance that people are informed about this feature present in computer devices and be advised to use it whenever using a computer device. This will reduce the electricity consumption of the devices and save electricity. Also, a great majority, about 58%, switch to low power consumption mode only when necessary. So more awareness needs to be spread among users telling them about the ill effects of carbon footprints due to electricity generation and what positive impacts power saving mode can have especially in the conservation of electricity.

Table-5: Increase of Global worming, carbon foot print

Question: Are you aware of the risk to the environment because of global warming, carbon footprint etc?				
	Option-1	Option-2	Option-3	Option-4
Options→	Aware	Somewhat aware	Unaware	Not Concerned
Number of persons	426	465	72	39
Percentage	43%	46%	7%	4%
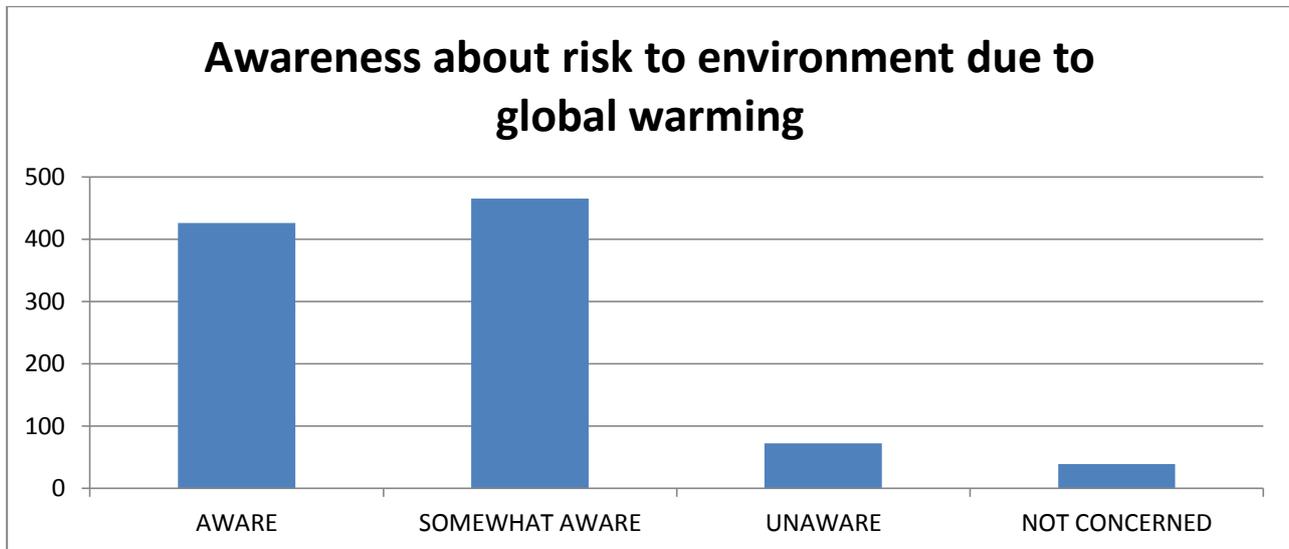
The survey depicts that most people are "somewhat aware" of the risks to the environment due to the environmental issues of recent times. The major issues being global warming, carbon footprints, climate change patterns, rapid degradation of non-renewable energy resources and so on. Out of 1000 people only 426 which is about 43% of the total claim to be completely aware of the present issues of the environment. We are not very much sure as to how many people have put forward a correct claim. 7% seem to be totally unaware of such problems. 4% are not even concerned. So the major problem in today's society is lack of awareness. The survey was carried out mostly among students, teaching staff or IT professionals. So if there is such a degree of unawareness among students and teachers then the percentage would be much greater if the survey is carried out among the common masses comprising of many illiterate people. If about 43% of the population is unaware about the risk to the environment then no step towards power conservation or reduction of carbon footprints can ever be initiated and the problems would always be neglected. If people fail to recognize the future environmental problems then the solution can never be found out. A group of scientists or environmentalists can never protect our environment from the detrimental effects of humans. It is the common masses who play a major role in fighting such issues. Therefore proper education needs to be imparted to people of all ages and professions about the way in which human activities are affecting the environment and how such activities will pose a major problem to the future of planet Earth and the human race.

Table-6: Lifetime energy consumption of a PC

Question: More than 80% of the lifetime energy consumption of a PC occurs before you buy it?		
	Option-1	Option-2
Options→	True	False
Number of persons	405	597
Percentage	40%	60%
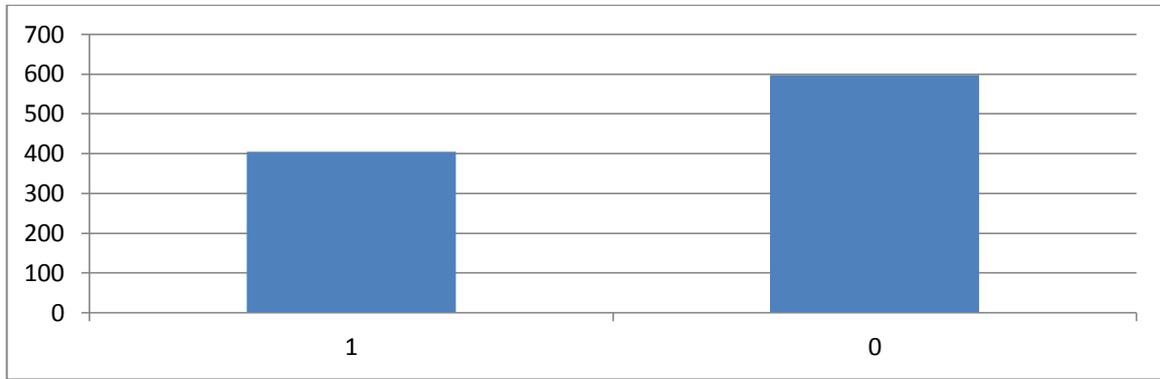
This survey shows majority of the people, about 60%, have the wrong notion that 80% of the lifetime energy consumption of a PC occurs after we buy it. This is not true. Majority of the lifetime energy consumption of a PC occurs before we buy it, during the manufacturing process. It is important that this information be spread among people so that they may use their computer devices sensibly and wisely, hence reducing the number of computer devices used by a particular person in his lifetime. This will in turn reduce the number of computers manufactured which will help conserve an enormous amount of energy. People should learn to use their devices for longer periods. They should not dispose devices when they feel it has become backdated and buy new devices in its place. People have to be informed that disposal should not be an option anymore, rather we should emphasise on upgradation. Upgrading a device will allow us to use new features in the same device without buying a new device. Collectively this scheme will reduce the carbon footprint and the impact on the environment on a large scale.

IV. CONCLUSION AND FUTURE SCOPE

Many issues in connection to green computing are to be addressed in the coming days. Therefore, there must be proper initiatives from all the stakeholders, as desired, shall surely enable the country to deal with the short term and long term pollution hazards with effective implementation, sustained monitoring and better supervisory practices. However, some apparently remaining unaddressed or less addressed issues require further consideration of the authorities towards devising the ways and means to ensure formulation of related strategic plans and subsequent necessary field level initiatives. The most important point is to find the first order priority is to identify informal sectors contributing for 95% of e-waste collection and recycling. Moreover, there is a need to create a system for absorbing the strong workforce of informal sector into the proposed scheme for scientific recycling. Quite a number of daily wage workers are involved in crude dismantling of these electronic items for their livelihood and their health is at risk, therefore, there is an urgent need to plan a preventive strategy among these workers. In school level and after school level education there must be a compulsory subject on "green computing". The leaders of all industries must take proper initiatives to minimize generation of carbon dioxide, poisonous material and minimum use of power. The authors also propose that skill enhancement of workers through training facilities and focus on their occupational health must be ensured. The Pollution Control Boards should take proper initiatives for strengthening of their resources, powers and plans for implementing green environment.

ACKNOWLEDGEMENT

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International Journal of Advance Research in Computer Science and Management Studies
Volume 3, Issue 4, April 2015 pg. 1-10

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