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Green Computing : Efficient Practices And Applications

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Abstract— **Today the importance of going green have been realized both in terms of environmental issues and cost minimization by implementing different strategies and policies by the ICT industry. Going green suggest the environmentally responsible practice of computers and related resources of ICT. For a sustainable environment, today Green Computing is an emerging topic, because of efficient power usage, minimal or no emission of carbon footprint, also proper disposal of electronic waste (e-waste) and many more, thus to take less participation in the global warming phenomenon. In this study, emphasis has given ondiminishing the energy and carbon footprint of computer and its related resources like- monitors, printers using green computing.**

Keywords- *Carbon Footprint; E-waste; Green Computing; ICT*

I. INTRODUCTION

Green Computing or Green IT is the knack of consuming different computing resources efficiently, eco-friendly and sustainably. This study and implementation is very reflects the concept of Green synchronization like less consumption of perilous resources, maximization of energy efficiency all through the lifespan of the product, promotion of recycling, and/ or industrial waste and outdated product biodegradation [1].

Today, behind the success of any organization Information Communication and Technology (ICT) plays a crucial role and is emerging day by day. Along with this, growing demand of energy is also rapidly increasing which is nearly 12 times faster compare to global energy demand [2]. The entire ICT sector consumes 6% of the global electricity consumption which includes electricity consumption of different network devices, computer and its peripherals, data centers and so on [3].Even electricity generation, computer and its peripherals, network devices, and data centers generates a huge amount of green-house gas like CO2 which emits in our environment. Nearly ICT contributes 2% of the Global CO2 emissions [3].

So intentionally or unintentionally, these can have different foul effects in the environment which affects the deadly global warming situation to some extent. Thus to save our environment today, the concept of Green Computing is significantly needed, which will make an efficient approach towards saving electricity, less amount of heat generation and reduced emission of carbon footprint by the different network devices, computer and its peripherals, data centers and so on to make a greener and sustainable environment. The time has come to educate people about the use of Green Computing in ICT and thereby save the environment.

In this era of computers, gizmos and electronic devices, energy issues and carbon emission issues will get a serious circlet in the upcoming days. The rate of energy consumption is increasingly by 20% a year and the world‘s energy consumption will almost double because of the ICT industry in the year 2030 [4].

Though from the perspective of performance wise, efficient design wise, capacity wise and others, computer design has evolved remarkably well and astonishingly fast but considering it from a green perception the work has barely instigated. Basically, the efficient use of computers and computing is what green computing is all about.

II. ISSUES RELATED TO GREEN COMPUTING

The following 4Gs' of Green Computing shows four different paths towards the utilization of resources efficiently, effectively, sustainably with minimal or no impact on the environment.

G-1: Usage of Green- Energy consumption of computers and other information and communication systems must be reduced and need to use them in an environmentally sound manner.
G-2: Disposal of Green- Old computers should be refurbished and reused, along with that unwanted computers and other electronic equipment must be recycled.
G-3: Designing of Green- Designing of different components, computers, servers, and cooling equipment should be done in an energy efficient and environmentally sound manner.
G-4: Manufacturing of Green- Manufacturing of different electronic components computers and associated sub systems should be done in such a way that its impact on the environment is none or minimal.

A. Dynamics of Green Computing

The following key forces have certain impacts in ICT, though a lesser degree, and have driven the need to adopt the practices of Green Computing [6]:

*1. Cost of Energy increasing:*The ICT is emerging day by day and as a result the required equipment (computers, accessories etc.), datacenters are also increasing. The power and cooling expenses required for these also increases in a higher rate. The ratio of power and cooling expense to equipment expenses have increased from approximately 0.1 to 1 in 2000 and 1 to 1 in 2007 [7].

*2. Increase use of Internet:*Today the increasing reliability on electronic data (e-data) can be seen among people. A rapid adoption of computerization, internet communication and media can be seen in the field of education and also industry. As on 2014, 18 out of 100 people usage internet in India [8].

*3. Increasing in server power and cooling requirements:*The growing rate of internet usage is more than 10% annually which leads to an estimation of 20% Compound Annual Growth Rate (CAGR) in the data center demand [9]. Efficiency in power consumption and cooling is a serious issue of data centers. An organization of 50 users required 3500 kWh annual server energy and approximately 2.0-2.5 Power User Effectiveness (PUE) for cooling [10].

*4. Low server operation rates:*Low server operation means organizations are engaged more in overpaying for energy, maintenance, operating support, rather than using a small percentage of computing capacity. The rate of server utilization is average 5-10 percent for large data centers.

B. Standards and Regulations

Several standards and regulations have been used in many organization for minimizing the energy and resources.

1. EPEAT: An evolution tool which has launched by Green Electronics Council, a non-profit organization, based in Portland, Oregon, USA [11] [12]. Electronic Product Environmental Assessment Tool (EPEAT) is anuser friendly resource for purchases, manufactures, resellers and others to identify devices that are environmentally sound. It is a universally rating system for greener electronics. This evaluation tool (EPEAT) of Green Electronics Council appraises the electronic product based on 51 criteria- 23 required criteria and 28 optional criteria [13]. These criteria are further reorganized into 8 performance classifications-

- Reducingand eliminating environmentally sensitive materials,
- Selecting materials,
- Designing for the product's end of life (such as recycling, reuse),
- Product longevity,
- Energy conservation,
- End of life cycle management,
- Corporate performance,

- Packaging

These classifications measure a product's efficiency and sustainability attributes.

2. *RoHS Directive:* The European Union adopted the Restriction of Hazardous Substances (RoHS) Directive in Electrical and Electronic Equipment in February 2003, whose main focus is to restrict the use of six hazardous materials- lead, cadmium, mercury, hexavalent, chromium or flame retardants within in a reasonable limits [5],[13].

3. *ICLEI- Local Governments for Sustainability:*The International Council for Local Environmental Initiatives (ICLEI) is an international organization, founded in New York City, USA in the year 1990 for the sustainable development at the national, regional and local level via several programs to address climate change and sustainability, including its Climate Mitigation Program, Climate Resilient Communities Program and Sustainability Program [14][15].

4. *ACPI:* An open industry standard, Advance Configuration and Power Interface (ACPI) allows directly controlling the different power- saving aspects of its underlying hardware by an operating system. Another Intel-Microsoft standard named Advanced Power Management, the predecessor of ACPI allows the Basic Input Output System (BIOS) of a computer to control the power management functions [13].

III. ANALYTICAL VIEWS OF GREEN COMPUTING

The main objective of Green Computing is to reduce power consumption and emission of carbon footprint. In this section, a discussion has been made regarding how to reduce the power consumption and carbon emission of the different equipment of ICT in terms of saving energy, increasing the life time of the product, and also for efficiency. The analysis is prepared upon computers and its accessories (like monitors, printers). In this analysis part, it has taken into consideration that the price of 1 unit of electricity= Rs. 6/- (1 unit of electricity= 1kWh electricity) and total hours usage per day= 8 hrs.

In general case, it is not a good exercise to use computers and its accessories 8 hours per day at a stretch and unnecessarily turning on computers, monitors and printers is not indispensable. In the analysis, it has taken into deliberation that in general case out of 8 hours per day, 5 hours computers and its peripherals are used and the remaining 3 hours it remains idle. The following study depicts that result.

A. Study on Computers (Desktop vs Laptop)

This analysis has been done on the basis of power consumption between desktop computers and laptop computers (excluding the power consumption of monitors).The average power consumption of desktop computers are 100 watts whereas laptop computers consume 60 watts in an average case [24]. From tableI, the monthly and yearly power consumption of desktop and laptop computers can be observed if it is used 8 hours per day. The monthly power consumption is a little bit higher in case of desktop computers.

TABLE I. POWER CONSUMPTION OF COMPUTER (8 HOURS)

Mode: Working (without monitor)	Total hours used per day: 8		
	Avg. power consumption (Watts)	*kWh per month*	*kWh per year*
Desktop Computer	100	24.35	292.2
Laptop Computer	60	14.61	175.32

But when it comes to consider the yearly power consumption, then rethink is needed. Though laptop consume less power than desktop but the power consumption should be taken care of in the both cases as 175.32 kWh per year (laptop) and 292.2 kWh per year (desktop), which is not a small amount of power consumption.

The tableIIdepicts,the power consumption of desktop and laptop computers on monthly and yearly basis, if computers are set in working mode for 5 hours. In sleep mode, the average power consumption of desktop and laptop are 35 watts and 16 watts respectively.Table III shows the monthly and yearly power consumption in sleep mode.

TABLE II. POWER CONSUMPTION OF COMPUTER (5 HOURS)

Mode: Working (without monitor)	Total hours used per day: 5		
	Avg. power consumption (Watts)	*kWh per month*	*kWh per year*
Desktop Computer	100	15.218	182.625
Laptop Computer	60	9.131	109.575

TABLE III. POWER CONSUMPTION OF COMPUTERS (3 HOURS)

Mode: Sleep(without monitor)	Total hours used per day: 3		
	Avg. power consumption (Watts)	*kWh per month*	*kWh per year*
Desktop Computer	35	3.1959	38.351
Laptop Computer	16	1.461	17.532

Calculating the power consumption of 8 hours (5 hours in working mode + 3 hours in sleep mode), in case of desktop the total monthly power consumption is 15.218 + 3.1959=18.4139 kWh and in annual 182.625 + 38.351= 220.976 kWh per year whereas in case of laptop the monthly and yearly power consumption is 9.131 + 1.461= 10.592 kWh per month and 109.575+ 38.351= 127.107 kWh per year respectively.

The result is reflected on the figure 1, which astonishingly leads to better results in both cases whether in terms of monthly or yearly power consumption of computers (8 hours of using per day) and also from the perspective of using desktop and/or laptop, that which one is better in case of power consumption.From the cost per month and cost per year perspective it also leads to a better result.

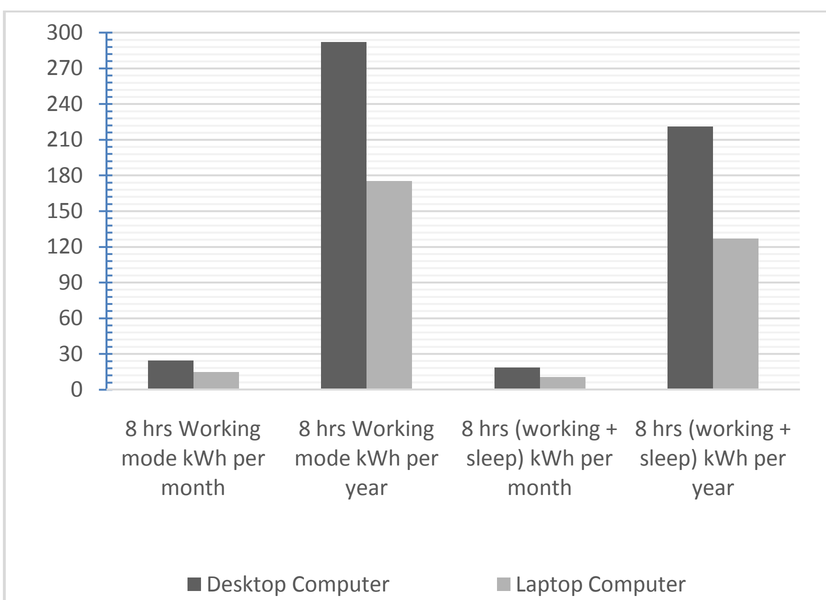

Figure 1.Comparison of power consumption in desktop and laptop

B. Study on Monitors (CRT vs LCD vs LED)

This analysis is also done on the basis of power consumption between different types of monitors, which are identical in sizes (17 inches).

- CRT (Cathode Ray Tube)
- LCD (Liquid Chrystal Display)
- LED (Light Emitting Diode)

The table IV illustrates the average power consumption of CRT, LCD and LED monitors on monthly and yearly basis, if it is used 8 hoursper day [23]. The monthly power consumption is comparatively higher in case of CRT monitors (CRT>LCD>LED).

TABLE IV. POWER CONSUMPTION OF MONITORS (8 HOURS)

Mode: Working	Total hours used per day: 8		
	Avg. power consumption (Watts)	*kWh per month*	*kWh per year*
17” CRT	75	18.26	219.15
17” LCD	20	4.87	58.44
17” LED	18	4.38	52.59

But when it comes to consider the power consumption in case of year, then reconsideration is necessary. TableVillustrates,the monthly and yearly power consumption of CRT, LCD and LED monitors if it is turning on for 5 hours.

TABLE V. POWER CONSUMPTIONOF MONITORS (5 HOURS)

Mode: Working	Total hours used per day: 5		
	Avg. power consumption (Watts)	*kWh per month*	*kWh per year*
17” CRT	75	11.414	136.968
17” LCD	20	3.043	36.525
17” LED	18	2.739	32.872

From table VI, it can be seen that in sleep mode, the average power consumption of CRT, LCD and LED monitors are 22 watts, 4.39 watts, and 2.21 watts respectively along with the monthly and yearly power consumption.

TABLE VI. POWER CONSUMPTION OF MONITORS (3 HOURS)

Mode: Sleep	Total hours used per day: 3		
	Avg. power consumption (Watts)	*kWh per month*	*kWh per year*
17” CRT	22	2.008	24.106
17” LCD	4.39	0.4008	4.810
17” LED	2.21	0.2018	2.421

Calculating the power consumption of 8 hours (5 hours in working mode + 3 hours in sleep mode), in case of CRT monitors the total monthly and yearly power consumption is 13.442 kWh and 161.074 kWh per year respectively whereas in case of LCD monitors it is 3.4438 kWh per month and 41.335 kWh per year and in the case of LED monitors the monthly power consumption is 2.9408 kWh per month and annually it consumes 35.293 kWh per year.

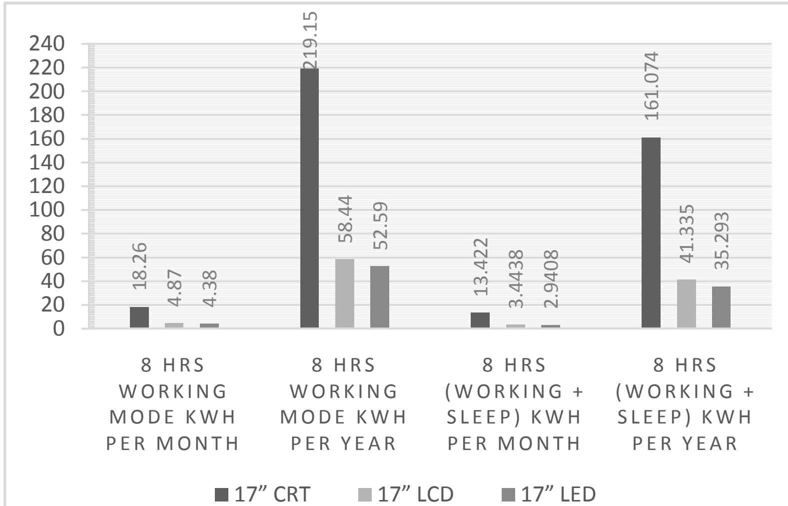

Figure 2.Comparison of power consumption in CRT, LCD and LED monitors

Figure 2 reflects the resultwhether in terms of monthly or yearly power consumption of monitors (8 hours of using per day) and which one is superiorto use in the instance of power consumption. It astonishingly leads to a better result in both circumstances and alsothe cost of electricity of month and year is superior of LED>LCD>CRT monitors.

C. .Study on Printers

The analysis is based on the power consumption between different types of printers, which are mentioned in the following-

- P1= All in one (wired) HP Officejet Pro 8610/8620/8630 e-all-in-one series
- P2= HP Officejet 100 mobile printer
- P3=HP Officejet Pro 251 dw Printer
- P4= XEROX ColorQube 8570 Color Printer[19] [20] [21] [22].

The average power consumption of the mentioned different types of printers on monthly and yearly basis is shown in table VII, if it is used 8 hours per day. The monthly power consumption is comparatively higher in case of printer P4 (P4>P3>P1>P2).

TABLE VII. POWER CONSUMPTION OF PRINTERS (8 HOURS)

Mode: Working	Total hours used per day: 8		
	Max power consumption (Watts)	*kWh per month*	*kWh per year*
P1	35	8.5225	102.27
P2	15	3.6525	43.83
P3	35.58	8.66373	103.964
P4	252	61.362	736.344

The table VIIIshows, the power consumption of the four printers on monthly and yearly basis, if printers are set in working mode for 5 hours.

TABLE VIII. POWER CONSUMPTION OF PRINTERS (5 HOURS)

Mode: Working	Total hours used per day:5		
	Max power consumption (Watts)	*kWh per month*	*kWh per year*
P1	35	5.3265	63.91875
P2	15	2.2828	27.3937
P3	35.58	5.4148	64.9779
P4	252	38.351	460.215

Theaverage, monthly, yearly power consumption of printer P1, P2, P3 and P4 in sleep mode and standby mode is described in table IX.

TABLE IX. POWER CONSUMPTION OF PRINTERS (3 HOURS)

Mode: Sleep	Total hours used per day:3		
	Avg. power consumption (Watts)	*kWh per month*	*kWh per year*
P1	2.20	0.2008	2.410
P2	2.6	0.2374	2.8489
P3	1.27	0.115	1.391
P4	45	4.1090	49.308
Mode: Standby	Avg. power consumption (Watts)	kWh per month	kWh per year
P1	6.90	0.6300	7.560
P2	5.8	0.5296	6.355
P3	4.71	0.4301	5.1609
P4	104	9.4965	113.958

The power consumption calculation of 8 hours is prepared in two aspects- 5 hours in working mode + 3 hours in sleep mode and 5 hours in working mode + 3 hours in standby mode, on monthly and yearly basis. In the instance of P1 printer, in working + sleep mode the total monthly and yearly power consumption is 5.5273 kWh and 66.32875 kWh per year correspondinglyand in working + standby mode it is 5.9565 kWh and 71.47875 kWh respectively. Whereas in case of P2 printerthe power consumption in working + sleep mode is 2.5202 kWh per month and 30.2426 kWh per year and in working + standby mode it is 2.8124 kWh per month and 33.7487 kWh per year.The printer P3 consumes in working + sleep mode 5.5298 kWh per month and 66.3689 kWh per year whereas in working + standby mode it consumes 5.8449 kWh per month and 70.1338 kWh per year.

The printer P4 is a laser printer and the power consumption is comparatively higher to other printers mentioned above. The following figure 4 depicts the power consumption of P4 printer from two aspects- working + sleep and working + standby on monthly and yearly basis.

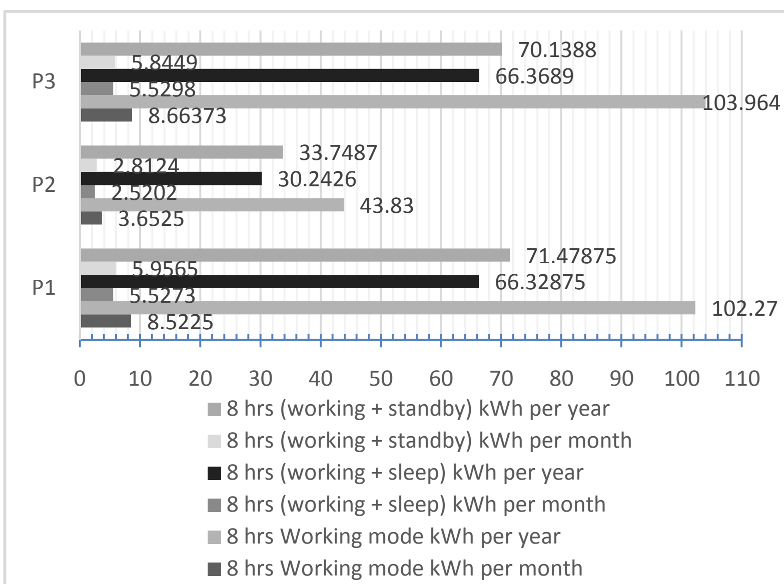

Figure 3. Power Consumption Comparison Chart of P1, P2 and P3 Printer

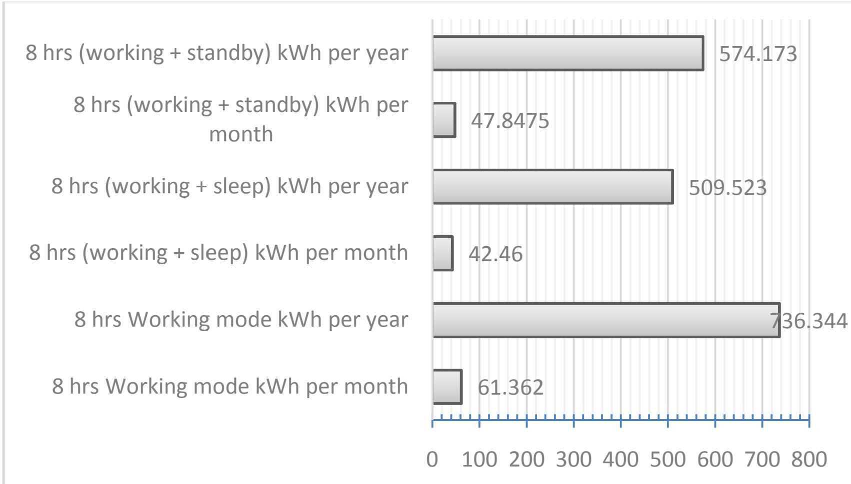

Figure 4.Power Consumption Comparison Chart of P4 Printer

The result is reflected in the figure 3 and 4, whether in terms of monthly or yearly power consumption of printers (8 hours of using per day). From the cost per month and cost per year perspective it also leads to a better result.

IV. Statistical data

Today many organizations are using Green Computing Lifecycle when designing and implementing different green computing technologies. The following statistical data is one of the reasons behind the implementation of green computing.

The following figure 5 analyzed the growth of population and power consumption of electricity in India from 2000-2014 and the trendis increasing upwards in terms of electricity consumption along with population. A statistical report says, in the year 2000 the consumption of electricity and population was 394.8025371 kWh per capita and 1.05 billion which has increased in 2014 to 882.592 kWh per capita and 1.29 billion respectively[23].

Increasing in electricity consumption leads to increase in the production of electricity which affects the CO_2 emission level due to fuel combustion in the production of electricity. Figure 6 depicts that statistical representation from year 2000-2012 of India [23].

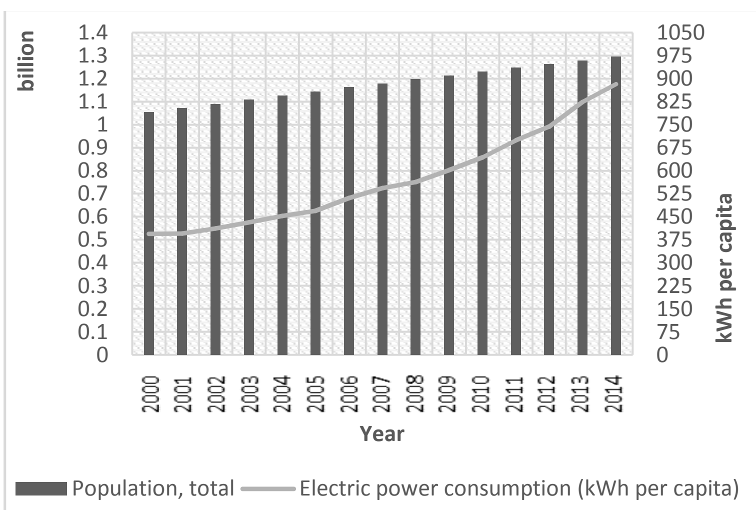

Figure 5. Population and electric power consumption comparison chart of India.

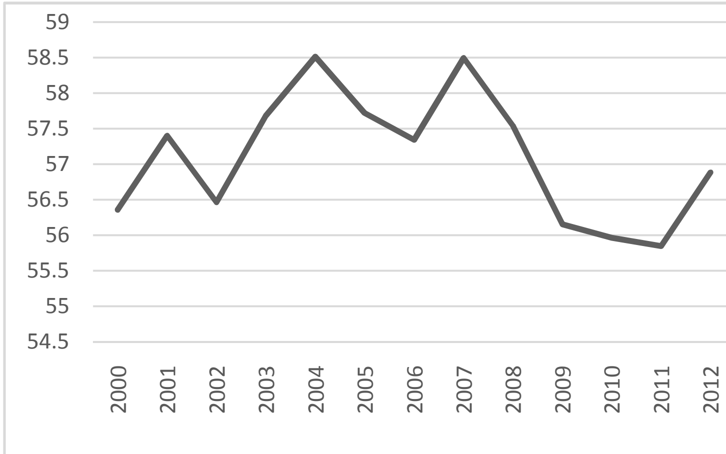

Figure 6. CO2 emissions from electricity and heat production, total (% of total fuel combustion) in India.

2% of the Global CO_2 emissions is done by the ICT. But the huge part of the CO_2 emission is produced only from PC's and its peripherals, about 406.7 million metric tons due to electricity consumption and heat generation [16]. According to figure 7, the statistical data shows the amount of CO_2has emitted from 2000-2011 in India [23].

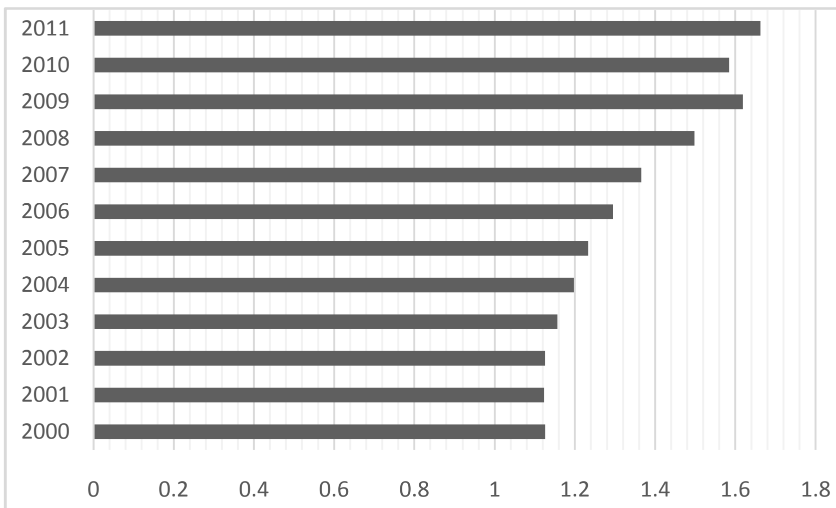

Figure 7. CO2 emissions (metric tons per capita) in India

V. CONCLUSION AND FUTURE PROSPECT

In this paper, the power consumption and carbon emission of computer and its peripherals has been given the primary focus and central objective. Researches are going on in this field, to reduce power consumption and emission of carbon footprint. Few researches are-

- Power aware hybrid deployment,
- Power management using Green Algorithm,
- Optimization of information resource tier,
- Architectural complexity reduction,
- Green Software [17] [18].

Network devices and data centers consume a huge amount of electricity and also emit carbon in a large scale. Data center's carbon emission stands second in the ICT's carbon footprint after computers and its peripherals. It is one of the today's vital area of research of optimizing data center's power management and emission of carbon footprint.

Along with researches, implementation is also going on. Some recent implementations are- Backle, Fit-PC,ZonbuComputers etc [12].

Not only researches and implementations will make an efficiently, eco-friendly and sustainable approach towards the Green Computing-Greener Environment, but also, the initiatives of each and every one should be needed whether in terms of focusing on the energy consumption or carbon emission. Thus to be a part of green computing today while using the computers and its peripherals, people should use energy star certified product, depending upon the purpose and use, selection of computer (desktop or laptop) is necessary, avoid the use of CRTs rather use LCDs or LEDs, unnecessarily turning on computers and peripherals must be avoided, effective power plan should be set, turning down the brightness of the monitors and screen saver use need to be avoided, informal disposing of computers should be stopped. Using the above Green Computing effect would make world greener defiantly.

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