Green Computing – A Case Study on the Holistic Approach of Innovative Computing

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***Abstract*-- With increasing computing needs, energy demands and environmental issues, green computing is the need of the hour. Green computing can be defined as the study of using computers so as to maximise energy efficiency, reducing the use of hazardous materials and employing the 3 R principle-REDUCE, REFURBISH and RECYCLE. This paper is a case study that takes stock of the current green efficiency of the monitors and CPUs of the CSE Department in RVCE and gives proposals and strategies to achieve higher green efficiency.**

I.INTRODUCTION

We should always try to strike a balance between the technological development and environmental sustainability known as holistic approach.. As computers are an integral part of technology, implementation of green computing is of utmost importance. At the undergraduate level among all the branches in RVCE,the CSE Department uses most number of computers. Hence this case study has been carried out to analyse the present green efficiency status of the computers used in the CSE Department.

This paper has helped us to get an insight as to how the green efficiency of systems on a small perspective can be enhanced and be extended to a larger perspective. Our work reveals the power requirements of monitors, CPUs and complete systems of the various models available in CSE Department. An AC/DC (0-125 W) wattmeter was employed for this purpose as shown in Fig 2 & 3. The role of different modes of a system and types of monitor in power management is analysed. The performance of different processors has been obtained by using standard benchmarks [1]. Considering the more efficient systems available in the market,good solutions have been proposed taking into account their power consumption and cost. The paper also deals with the Green rankings [2] of IT companies based on various environmental issues. Finally, we propose strategies that are innovative, which will enable us to save on electricity and reduce greenhouse gases without compromising usage of the computers.

II.CASE STUDY

A. Experiment

1) Aim: to measure electric power consumed by monitor, CPUs and a system as a whole of various models in CSE Department.

2) Apparatus: wattmeter, spike buster, connecting wires, monitor, CPU.

3) Procedure: Connections are made as shown in Fig 1. The load for the wattmeter is a monitor or CPU or system as the case may be. Readings for various cases are tabulated. Using these readings energy efficiency of various models of computers in CSE Department is analysed.

Table 1
Experimental Results

Current Stock			**Wattmeter Readings**			
Models	**Processors**	**Monitors**	**Initial Readings**	**Case 1: System full on**	**Case 2: CPU on monitor off**	**Case 3: CPU off monitor on**
HP DX2000	P4	HP5500 (CRT)	0	140	84	0
HP DX2700	Core 2 Duo	HPL1506 (LCD)	0	70	54	2
Acer Veriton	Core i5	V173 (LCD)	0	48	32	0
HP DX7480	Core 2 Duo	HPLV1561W (LCD)	0	60	46	4
IBM Think Centre	P4	IBME54 (CRT)	0	126	78	4
Lenovo Think Centre	Core 2 Duo	9165AC6(LCD)	0	60	46	4

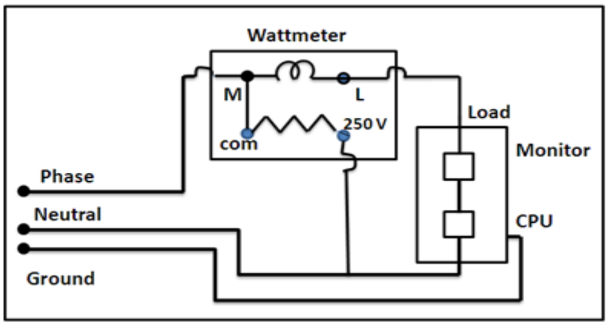

Fig 1 Circuit Diagram

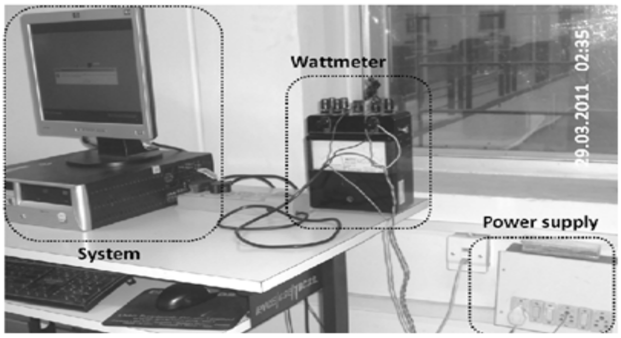

Fig 2 Experimental Setup

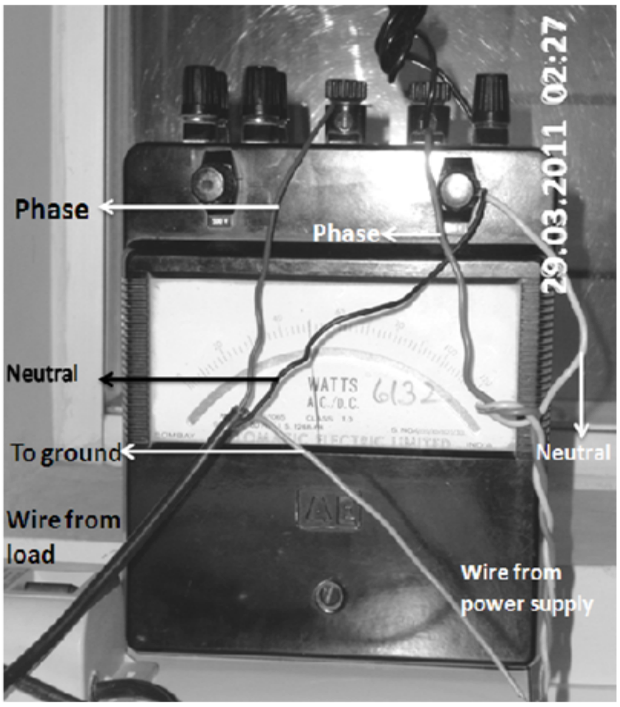

Fig 3 Wattmeter connections

B. Analysis

1) Monitors:

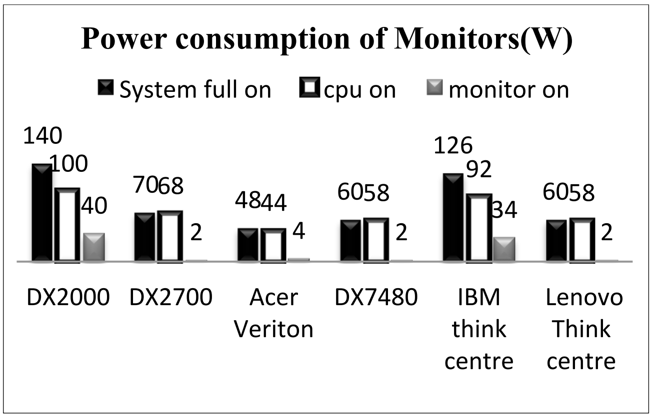

Fig 4 LCD Vs CRT

a) LCD vs. CRT: The graph is plotted on power consumption versus various models. In the Fig 4 the bar in black depicts power consumed when system is full on and is idle. The bar in white gives the power consumed when CPU is on and monitor is off. The power consumed by the monitor only for display is got by black minus white given by the grey bar as shown in Fig 4.Itdepicts that LCDs consume less power than CRTs. Amongst the LCDs in the CSE Department, Acer Veriton (V173 LCD) consumes least power.

b) Power down Options for Monitors: In a survey of PC users of CSE department, slightly over half say they are not currently using their PCs' power management capabilities, such as sleep and hibernate modes, to save power when they're not actively using the systems. Fortunately, nearly all users who are not currently using power management acknowledge that they would like to change their ways. Windows users have three choices every time they walk away from their computers i.e.: to put the computers standby or hibernate or shut them down [3].

Standby: The computer keeps the applications running and documents open. Power is being fed to the computer memory, but peripherals are powered off and the hard drive power is minimized. The computer "wakes up" quickly from standby mode and regains its previous state. The biggest drawback of standby mode is the power usage, and it should only be used when leaving the computer for a brief period.

Hibernate: It recalls all open documents and applications, but shuts down power to the computer. The computer takes longer to regain its previous state as it wakes up from hibernation compared to standby mode. The hibernate mode uses no power, but it is still active enough to automatically restart and begin using power again.

Shut Down: It powers off your computer completely. It's always the best option when you are not using your computer for a while. It is the best environmental option because it draws no power, and can even safely unplug the computer or shut off the power strip to the computer and all the other office peripherals.

c) Energy Saved by replacing current CRTs with LEDs:

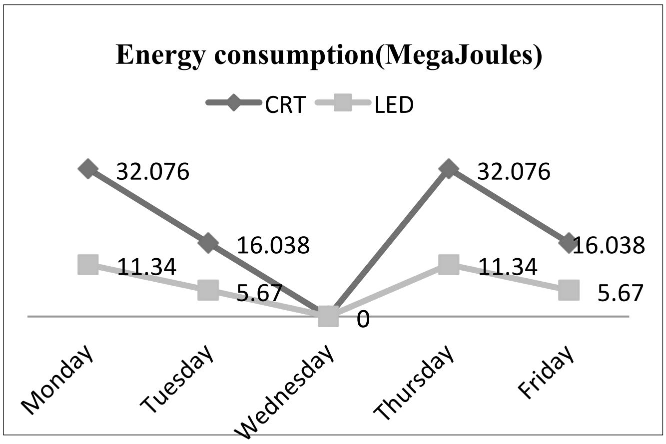

Fig 5 Energy consumed by the CRTs and LEDs in the Labs of CSE Department per day.

The graph shows the energy consumed by CRT monitors in the labs on different days of the week(On Wednesday no labs are conducted according to the time table). If we replace CRT by LED then we can save 20.736MJ on Monday and Thursday. Likewise 10.368MJ can be conserved on Tuesday and Friday. Hence, 248.832MJ of energy can be saved over a month.

2) Processors:

a) Test Bed: Using CPU Benchmark results ("Baselines") got from the Pass Mark web site[1] as well as from internal testing, Performance Tests for the various processors of the computers in CSE Dept. were conducted. This consisted of eight different tests and the averages of the results determined the CPU Mark. The following lists the tests performed- Integer Math Test, Compression Test, Prime Number Test, Encryption Test, Floating Point Math test, SSE/3D Now Test, Image Rotation Test, String Sorting Test and String Sorting Test[1].To ensure that the full CPU power of a PC system is realized, Performance Test runs each CPU test on all available CPUs. Specifically, Performance Test runs one simultaneous CPU test for every logical CPU (Hyper-threaded); physical CPU core (dual core) or physical CPU packages (multiple CPU chips). So hypothetically, if one has a PC that has two CPUs, each with dual cores that use hyper-threading then Performance Test will run eight simultaneous tests [1].

Steps followed to measure performance of a CPU:

- Download and install Performance Test.
- Start Performance Test then from the menu bar select "Tests->Run All Tests".
- Once the tests have run select "Baseline->Upload Baseline to Web".

b) Performance

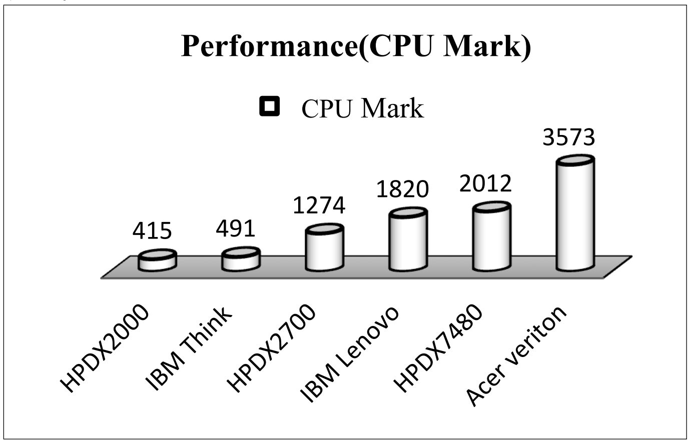

Fig 6 Performance based on the CPU mark of the Processors

Based on the performance of our processors obtained as per the described test bed, Fig 6 was plotted. It shows Intel core i5 3.2GHz (Acer Veriton) has highest performance where as Intel pentium4 2.8 GHz (Hp DX2000) has least performance among the processors of the computers in the CSE Department.

c) Performance/Power Ratio (P/P Ratio)

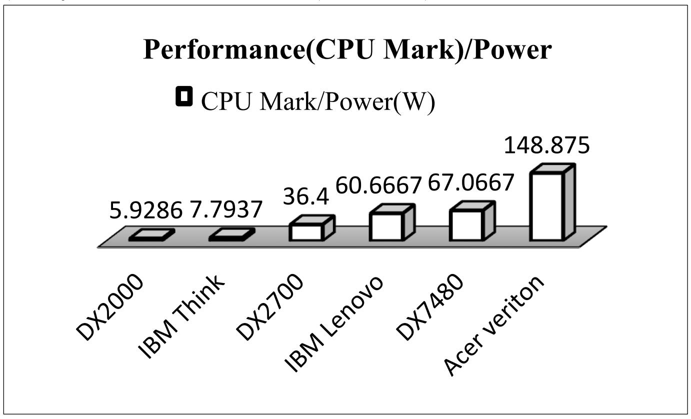

Fig 7 Efficiency of Processors based on Performance and Power consumption currently used in the CSE Department

The processor with best power and performance efficiency is obtained by evaluating performance/power (P/P) ratio. Power consumed by each processor is taken from the case-2(CPU on and monitor off) as shown in Table 1.The performance/power ratio is high when the performance is high and power consumed is less. Therefore the processor which has the highest performance/power ratio is more efficient. It can be seen from the graph that Intel core i5 3.2GHz (Acer Veriton) has highest P/P ratio. Therefore it is more efficient but not necessarily the most greenefficient. This will be dealt with further in the paper.

d)Performance/Power/Cost Ratio

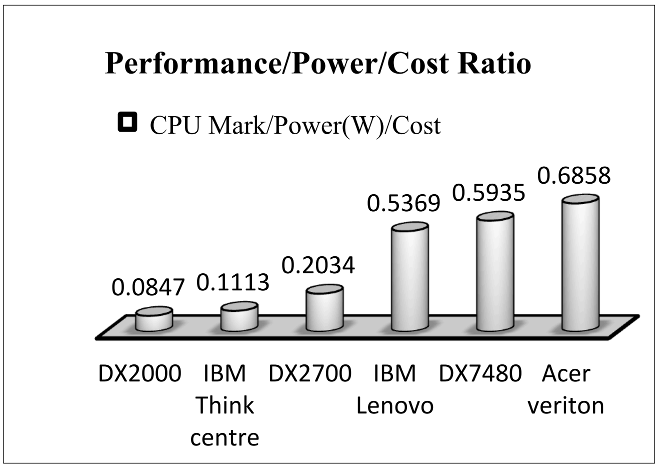

Fig 8 Efficiency of Processors based on Performance,Power Consumption and Cost currently used in the CSE Department

A processor has to be selected in such a way that it has a high P/P ratio and is cost effective. A processor which has a high performance/power/cost(P/P/C) ratio than the rest will be the optimal solution.We see from the graph that even taking cost into account Intel core i5 3.2GHz processor retains its position at the top. From the case study we conclude that Intel core i5 3.2GHz(Acer Veriton) is more efficient and cost effective.
Now we will see the green rankings[2] of various companies, analyse where each manufacturer stands,if they are green efficient or whether there are greener alternatives.

III.PROPOSALS

A. Opt fir Manufacturers who have Greener Scores:

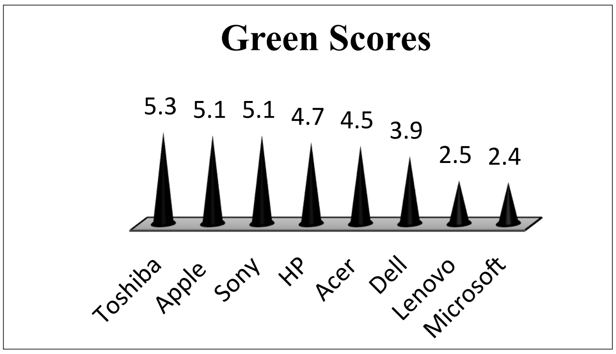

Fig 9 Higher the Green Score[2] Higher the Green Rank

1. Toshiba (5.3) - Good score on toxics elimination.
2. Apple (5.1) - Continues to improve with best score on toxic chemical elimination and e-waste criteria.
3. Sony (5.1) - better energy totals.
4. HP (4.7) - Clear support for global emission reductions.
5. Acer (4.5) - Acer is lobbying for stronger chemical legislation.
6. Dell (3.9) - Lowered because of energy criteria and delaying phase out for toxics.
7. Lenovo (2.5) - Penalty point for indefinite phase out of toxics.
8. Microsoft (2.4) - Fails to support strong chemicals legislation.

From the Green Score graph it can be seen that Acer stands in 5th position. Therefore, in future, if there is a need to replace existing systems they can be replaced by the models which are more green efficient than Acer.

B. Do as much Toxic Free Computing as possible:

Toxic chemicals [11] are used in the manufacturing of computers and their components, which, on entering the 4 spheres(Lithosphere,Biosphere,Hydrosphere and Atmosphere) of the environment cause hazardous effect on the ecosystems.

Chemical Elements Found in Computers and Components:

- Elements in bulk: Lead in CRT monitors and Lead-acid battery, tin in solder, copper in copper wire and printed circuit board tracks, silicon in glass, transistors, ICs and printed circuit boards, carbon in steel, plastics and resistors, iron in casings & fixings and aluminum in nearly all electronic goods are used.
- Elements in small amounts: cadmium in nickel-cadmium rechargeable batteries and mercury in fluorescent tubes.

Toxicity can be reduced by employing Restriction of Hazardous Substances (RoHS),Carbon free and Solar Computing.

C. Opt for LED monitors wherever possible:

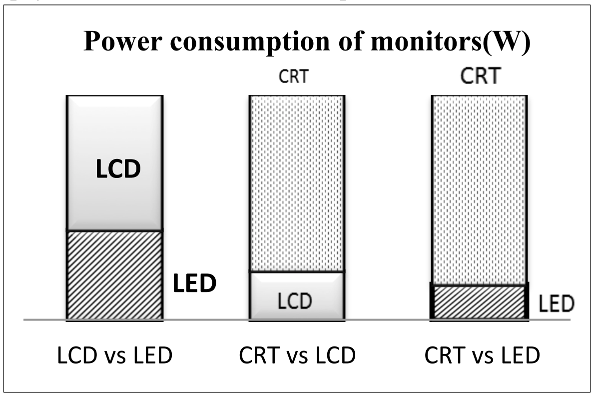

Fig 10 Comparison of LCD, LED and CRT Monitor based on Power consumption

From Fig 10, it is apparent that power intake by CRT (76W) is more when compared to LCD (21W) and LED (14W) [4]. In our case study, among the monitors we had LCDs are greener than CRTs. but from Graph 6 it is evident that LED monitors are greener than LCDs with just 15-20% difference in cost. So to become greener efficient CSE Department can go with LEDs.

D. Opt for Processors with high P/P ratio:

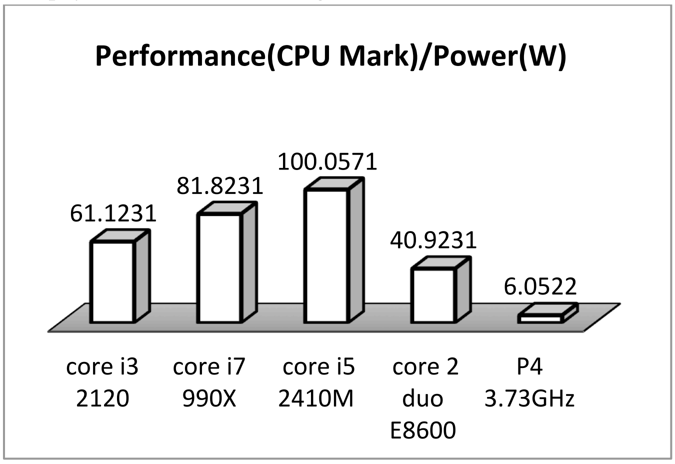

Fig 11 Processors with best Performance (CPU Mark) compared taking into account their Thermal Design Power (TDP)[5]

In each type of Intel processors [6-10], we have considered the one with the best performance. An analysis of the processors as shown in Fig 11 has been done based on their respective P/P ratio similar to Section II.B.2).b) to arrive at an optimal solution as to which processor can be used to replace the existing ones in the CSE Department. All the system models in CSE Department have only Intel processors, so we have considered only the best performing Intel processors in each category (p4,core 2 duo,i3,i5,i7).As shown earlier in this paper a higher P/P ratio for a processor is directly proportional to its green efficiency.i7 has the highest performance[1],but from Fig 10 it can be inferred that after taking power consumption into account i5 has emerged more energy efficient compared to the others. Hence CSE Department can go with i5 processors to achieve higher green efficiency.

E. Adjust the frequency and voltage of CPUs and cores (in multicore infrastructures) according to the workload in order to reduce the energy consumed without too much penalty to the performance.

F. Use Virtualization to achieve green data centers.

G. Try to design and employ energy efficient hardware and algorithms.

IV. POINTS TO NOTE

- Avoid using screen savers. They are not necessary on modern monitors and they actually consume more energy than allowing the monitor to dim when it's not in use.
- Turn down the brightness setting on the monitor as the brightest setting consumes more power compared to the dimmest setting.
- Turn off peripherals such as printers, scanners and speakers when not in use and close unused applications.
- Use a laptop instead of a desktop as they consume lesser power.
- Establish multiple power schemes to address different usage models. For example, you can create a power scheme for playing music CDs that shuts off your hard drive and monitor immediately, but never puts your system into standby mode.

V.CONCLUSION

The benefits of green computing, in terms of reducing power consumption are direct and relatively rapid to achieve, and everyone should strive to conserve energy. The notion of green computing is transitioning from wishful thinking into a strategic engineering. Making a green impression by ensuring that our workspaces are eco-friendly is essential. Small changes can make a big difference like using energy saving computers and power management software to cut down on costs, recycling old computers and ink cartridges, skills and knowledge about how to reduce or eliminate environmental stress.

The most interesting aspects of this case study is that it has helped us to analyse a computing system based on the four most critical parameters namely power consumption, performance, green scores[2] and cost.

Our further studies would involve developing automated software that helps an organisation to realise their green efficiency status and suggest optimal solutions to become green.

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