Going Green in University Computer Labs

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We investigate energy consumption in university computer labs, in order to determine strategies for reducing energy costs without adversely affecting lab users. This research is part of a multi-stage project that incorporates data gathering, analysis, solution exploration, model development, and strategy implementation. In this paper, we report primarily on the first three stages, along with some discussion of strategy implementation. The initial data gathering was conducted at Abilene Christian University (ACU), across five computer labs, with over 100 computers surveyed. These computers have been used as a representative sample of computer configurations across the ACU campus, due to their near uniform hardware and software configurations according to the university's IT policies and procedures. Based on our data collection, we compared the computers' idle time with their actual usage time, and show that a large amount of energy is being unnecessarily wasted. With this data, we calculated the current energy usage of the surveyed computers, and then extrapolated our findings to the rest of the university based on ACU's computer lab equipment list. Simple strategies such as switching computers to sleep soon after class, running a campaign to switch off monitors, and waking the computers on LAN, are shown to substantially reduce energy waste. Across ACU, we estimate thousands of dollars per year in savings. Finally, we also discuss concerns and challenges related to the proposed strategies, and proffer some solutions to illustrate the feasibility of our recommendations.

INTRODUCTION

Abilene Christian University (ACU) is a selective, private, master's-level university located in Abilene, Texas. Enrollment for the 2010-2011 fall semester was 4,728, while average enrollment is about 4,700 (ACU Profile, 2012). According to the university's education technology list of equipment, there are over 750 computers in university labs, classrooms, and offices, with the majority being Dell desktops running Windows XP or Windows 7. Our research began with the observation that ACU, like most universities, did not seem to have specific energy conservation strategies in place (particularly for their lab computers). Even though some of the labs are only used for a few hours of the day, the computers are almost always on, including over nights, weekends, and holidays. This led us to believe that there was potential for ACU to save a considerable amount on energy costs through the creation and implementation of various energy conservation strategies. From our initial literature review, we found that ACU is not alone in this regard - energy conservation issues also affect many other universities. According to a study done at the University of Louisiana at Lafeyette, computers are rarely turned off, even if not in use (Kozman et. al, 2011). Similarly, improving energy efficiency could be beneficial for businesses. According to New Zealand's Energy Efficiency & Conservation Authority, if their business sector were to improve its energy efficiency (cost effectively), over $2 billion per year could be saved (New Zealand Management, 2011).

With this knowledge, we sought to determine whether or not ACU was making efficient use of its energy, and if not, what could be done to improve. The major aspects of this research included data collection, analysis, and solution exploration, though in the future we would like to expand this research to model development and strategy implementation. After collecting the relevant data (computer type, quantity, power settings, etc), we analyzed this information to determine how much we could improve energy efficiency at Abilene Christian University. In this analysis, we share some possible solutions, and also discuss their related challenges and concerns.

DATA COLLECTION

To begin our research, we surveyed the Mabee Business Building, which is a part of the College of Business Administration at ACU. We began with this building primarily due to its ease-of-access, and because it had multiple computer labs. We also surveyed a computer lab in the Zona Luce Building, which is a part of the Department of Agricultural and Environmental Sciences. In total, we counted 138 computers in the surveyed labs and classrooms (see Table I), with the majority being Dell Optiplex 380 workstations (64%). The second and third most popular computer types were Dell Optiplex 330s (14%), and 20" Apple iMacs (9%). In addition to this, we counted 135 monitors (see Table II). The discrepancy between the total desktop and total monitor count can be attributed to a small group of computers with dual monitor setups, and also to the 20" iMacs (where the monitor is considered to be a part of the desktop unit).

TABLE I
COMPUTER TYPES AND QUANTITIES

Computer Type	Quantity
20"Apple iMac	13 (9.4%)
Apple Mac Mini	2 (1.4%)
Dell Optiplex 330	19 (13.8%)
Dell Optiplex 360	11 (8.0%)
Dell Optiplex 380	88 (63.8%)
Dell Optiplex 390	4 (2.9%)
Dell Precision 350	1 (0.7%)

During the 2012 spring break, when the majority of students were not on campus, we again surveyed some of the labs where these computers were located, in order to determine whether or not the computers were on or in use. Of the 100 computers surveyed during this break (Mabee Business Building labs 314, 315, 317; Zona Luce lab 104), only nine machines were turned off (less than 10%), though none were in use at the time of this survey (~11am on Wednesday).

TABLE II
MONITOR TYPES AND QUANTITIES

Computer Type	Quantity
Acer X193W+	21(15.6%)
Aquos Quattron (TV)	2 (1.5%)
Dell 1909W	88 (65.2%)
Dell 1702FP	1 (0.7%)
Dell E1709W	4 (3.0%)
Dell E198WFP	19 (14.1%)

After determining both the type and quantity of the equipment found in the classrooms and computer labs, we attempted to determine the equipment's power consumption during various states of power (e.g. on, sleeping, and off) by cross-referencing the Energy Star product list and the device manufacturer's specifications (see tables III and IV) (Energy Star, 2012a). Since Energy Star has the resources to accurately measure equipment power consumption, we decided to use their data rather than measuring equipment power consumption on our own.

TABLE III
DESKTOP POWER USAGE IN VARIOUS STATES

Computer Type	Watts (On)	Watts (Sleep)	Watts (Off)
20" iMac	26.17	1.49	0.61
Dell Optiplex 360	39.36	1.12	0.52
Dell Optiplex 380	49.40	1.27	0.88
Dell Optiplex 390	36.97	2.64	0.26
Mac Mini 4,1	12.40	1.57	0.61

TABLE IV
MONITOR POWER USAGE IN VARIOUS STATES

Monitor Type	Watts (On)	Watts (Sleep)	Watts (Off)
Acer X193W+	17.06	0.34	0.3
Aquos Quattron	NA	NA	NA
Dell 1702FP	NA	NA	NA
Dell 1909W	17.68	0.43	0.35
Dell E1709W	19.37	0.43	0.4
Dell E198WFP	NA	NA	NA

One of the most interesting findings of this initial mapping was that the most common computer (Optiplex 380) was also the one with the highest power usage of the computers surveyed (see table III). Consequently, we determined that it was imperative that good solutions be found to reduce power consumption. At the same time, one of the least used machines (Mac Minis) had the lowest power consumption. However, this difference in quantity can be partially attributed to their difference in price ($369 vs $599). In the 'on state', an Optiplex 380 uses about four times more power (.049 kW) than a Mac Mini (.012 kW). Interestingly enough, the 20" iMacs use roughly half the power (.026 kW) that the 380s use, despite having 20" displays built into the system. In contrast, the Dell 1909w monitors that accompany the 380s use about .018 kilowatts (in addition to the desktops' .049 kW).

We then checked the various computer types and determined their configured time-to-sleep and time-to-off (per lab), as these settings have the potential to greatly impact energy consumption. We found that none of the computers were configured to completely turn off after any period of time, and only 21% (29 of 138) were configured to go to sleep after some period of time (see table V). The default (factory) power settings for these computers would normally cause them to sleep after 10, 15, or 30 minutes, so it appears that this setting has been changed as a part of ACU's desktop imaging process. However, 122 (88%) of the desktops were configured to turn off the monitors after some period of time (see Table VI). We also found that for monitors, there was very little difference between power used when sleeping and off, though there was a slightly bigger difference for the same comparison with desktops (see tables III and IV).

TABLE V
COMPUTER TIME-TO-SLEEP VS MANUFACTURER DEFAULTS

Computer Type	Time-to-sleep	Defaults
20" Apple iMac	3 hours	10 minutes
Apple Mac Mini	3 hours	10 minutes
Dell Optiplex 330	None	NA
Dell Optiplex 360	15 minutes	15 minutes
Dell Optiplex 380	None	30 minutes
Dell Optiplex 390	15 minutes	15 minutes
Dell Precision 350	None	NA

TABLE VI
MONITOR TIME-TO-SLEEP VS MANUFACTURER DEFAULTS

Monitor Type	Time-to-sleep	Defaults
Dell E198WFP	20 minutes	NA
Acer X193W+	15 minutes	15 minutes
Dell 1909W	60 minutes	15 minutes
Dell E1709W	60 minutes	15 minutes
Dell 1702FP	0 minutes	NA
Aquos Quattron	0 minutes	10 minutes
Dell E198WFP	20 minutes	NA

It is important to note that though some of the computers have been configured to turn on a screensaver after a few minutes, these screensavers do not save any power. According to Energy Star (Energy Star, 2012b), most screen savers do not save money, and some graphically-intense screen savers may actually double a computer’s rate of energy consumption and prevent it from entering sleep mode. In our survey, the monitor power consumption seemed to be a fairly significant finding, as the monitors, though modern, draw a lot of power. Even when the system is simply updating or displaying an all black screensaver, the monitors are operating at full power.

ANALYSIS

After we finished collecting the necessary data, we began to analyze our findings to determine whether or not we could improve the energy efficiency (and if so, by how much).

Assumptions

In order to simplify the data analysis, it was necessary to make a number of base assumptions.

- All computers (of the same model) have identical specifications. Based on ACU's IT policies, computers of the same type usually have identical system images. We verified this by checking computers of the same type in different labs, and all computers surveyed appeared to have the same specifications.
- Based on classroom and lab schedules, all computers that are configured to go to sleep will do so once per day. In actuality, some computers with a short enough time-to-sleep/off will go to sleep between classes, which increases the idle time per computer per day (in contrast to continuous usage, where all computers would go to sleep/off only once per day).
- Classes are assumed to use all computers. In practice, some classes may not use all of the available computers.
- Computers are assumed to not be in use outside of classes. In practice, some students may use the lab computers outside of class, increasing the 'on time'.

Data Analysis

Keeping these assumptions in mind, we began to analyze the data we had collected. In order to determine the hours per day that the surveyed computers were in use, we referenced the class schedule for each lab (MBB Course Schedule, 2012). Using the class information for the spring 2012 semester, we then calculated the actual usage by taking the hours in-use, averaging them per day over a week, and then adding the time-to-sleep/time-to-off for each day (where applicable).

In the case of labs 314, 315, and 317, the computers are almost always on, but are not in use for the vast majority of the time. This is clearly not an efficient use of power, and can certainly be improved. Though unexpected, this has led to discussions of completely removing these lab computers, and instead possibly requiring students to have a laptop as a part of admission to an SITC program at ACU. These three labs contain 82 computers total (59% of all surveyed computers), and use a significant amount of power. On the other hand, lab 214 and 302 are good examples of efficient energy use. In lab 214, the computers are configured to go to sleep after 15 minutes, while the iMacs in lab 302 are configured to go to sleep after 3 hours. If we were to set similar settings for all computers, we could greatly reduce the idle time, thereby reducing overall energy costs. An interesting finding was that only the Optiplex 360s and 390s (10.9% of all surveyed computers) were configured with the manufacturer defaults regarding system power settings. The configured time-to-sleep/time-to-off for all other surveyed computers was much higher than the manufacturer defaults. For example, the Optiplex 380s were configured to never turn off or sleep, and the iMacs were configured to go to sleep after 3 hours.

Potential Savings

Using the aforementioned data, we began to calculate the costs and potential savings for the surveyed computers. During the 2010 fiscal year (up to May 2011), the average cost of electricity was 8.1cents per kWh. In the 2011 fiscal year, the average cost was 8.72 cents per kWh. ACU is contracted to buy electricity at a set rate up to an agreed cap, beyond which the electricity cost is set at the market rate. Not including the equipment for which we do not have the necessary power usage data, with the current power settings, we estimate the total kilowatt hours used per day to be a little over 90. At 8.72 cents per kWh, this translates into almost $8 per day. At first glance, this may not seem like much, but the typical computer upgrade cycle at ACU is three years (though it often gets stretched to four years for a variety of reasons). In one year, at 8.72 cents per kilowatt hour, these computers would cost the university over $2,800 to run (or around $8,500 in 3 years). However, if the power settings for all lab equipment were to be reset to the manufacturer defaults, the kilowatt hours used per day would drop to *less than 7*. At the same 8.72 cents per kWh, this comes to a little more than 50 cents per day, or about $200 in a year. This translates into cost savings of over $2,600 per year, and about $8,000 over three years. If the upgrade cycle is extended to four years, as it often is, the savings would be closer to $11,000. With 750 computers on campus, if the other computers have similar power settings, there could be significant savings across the university. In our preliminary comparison, extrapolating the data across campus could save ACU almost $20,000 per year.

FIGURE 1
ACTUAL USAGE VS TIME ON, AVERAGED PER DAY OVER A WEEK

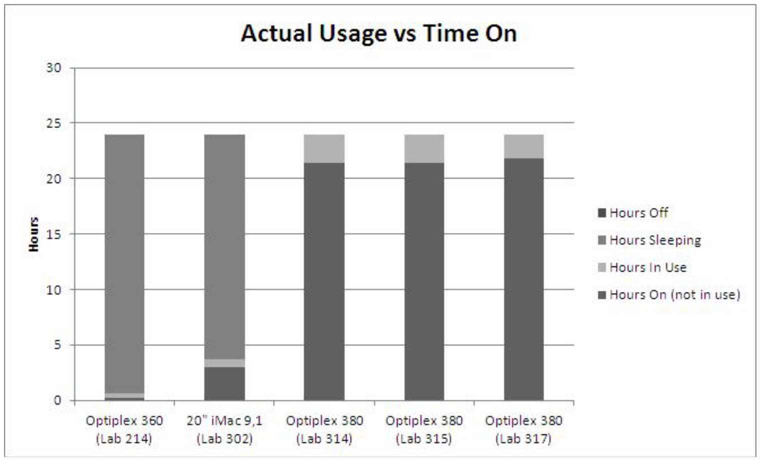
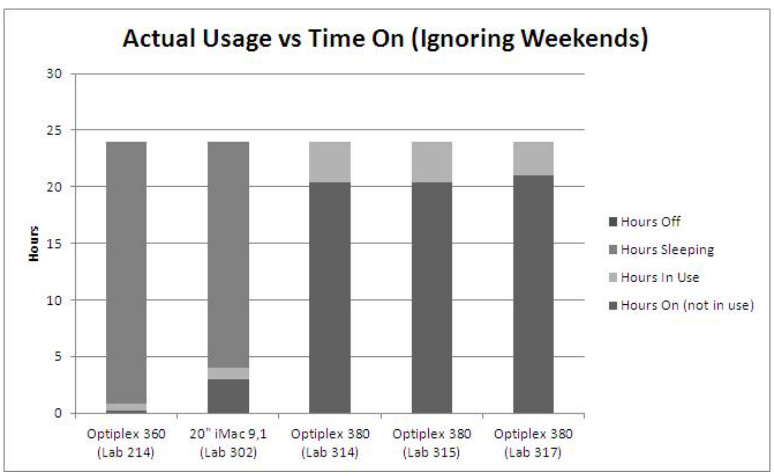


FIGURE 2
ACTUAL USAGE VS TIME ON, AVERAGED PER DAY (IGNORING WEEKENDS)



SOLUTION EXPLORATION

After collecting the data and doing a preliminary analysis, we began to discuss the possible solutions. The most obvious answer would be to change the power settings for lab computers (which seems to be a fairly simple solution), but due to ACU's management software and policies, this is not easily doable. Also, based on the overall low usage time of the lab computers in Mabee Business Building, we began to discuss the possibility of reducing the number of lab computers, or even removing them completely. This could bring significantly more savings to the university, but would require a detailed study of the power usage and effective cost of requiring students to bring their own laptops. This would also lead to a number of new issues that would need to be addressed (e.g. standardizing hardware requirements, access to software, device and network security, etc). To complicate matters further, many students already bring their own computing devices to class (including laptops, tablets, smart-phones, etc).

Despite the fairly significant potential benefits to implementing stricter power settings for the equipment, there are some challenges and concerns that must be addressed. At ACU, computers are left on due to the remote management software used by the system administrators. This software is used to maintain, update, and image computers, but since ACU does not currently use wake-on-LAN, computers must be left on all the time. Under the current university configuration, most computers are "frozen" in a certain state with Faronics' computer management software "Deep Freeze", in order to prevent lasting unwanted or dangerous changes (Deep Freeze Enterprise, 2012). Any changes made to a computer while in this frozen state are completely rolled back when the system next restarts. Partially because of this, updates to computers must be done overnight, or during some other time when they are not in use. They are automatically "thawed", updated, and refrozen. However, even though Deep Freeze can remotely thaw machines for maintenance and updates, it does not look like this is occurring, at least not regularly. In at least one lab, most of the computers had a number of Windows updates that had not been applied.

Wake-on-LAN (WOL) is a technology that allows computers to be woken up remotely by a special Ethernet packet sent to their network interface cards (NIC) (McKaughan et. al., 1998). Some IT managers at ACU have discussed switching from Altiris to Dells' Kace system. Kace works with wake-on-LAN technology, and would allow system administrators to shutdown computers without worrying about remote updates and maintenance. Also, since we determined that monitors can have a fairly significant impact on energy usage, we proposed the idea of implementing a simple "Switch-Off-Screens" campaign", where we would encourage students through word of mouth. However, if we were to attempt such a campaign, uninformed students may think a computer is off when only the monitor is turned off, possibly wasting class time by forcing the machine to undergo a hard reset.

FUTURE RESEARCH

In the future, we would like to expand our research to other buildings on ACU's campus, and possibly to other universities. One possibility is the development of a public energy savings calculator, so that universities could quickly and easily input the number and type of computers, as well as their class schedule and computer power settings, in order to receive a good estimate of their potential for savings. Dell has a Client Energy Savings calculator available on their website, but it is missing some parameters that universities may find useful (and only takes into account Dell equipment) (Dell Inc, 2012). Another possibility for future research is an investigation of wake-on-LAN technology. This technology has been proven to work, but why is it not more commonly used? A paper dealing with WOL would discuss its potential benefits and issues, as well as the details of its implementation. In addition to this, we will work on developing a model for energy conservation at the university level. Finally, a study of student computers/devices and study habits could be useful in determining the necessity of having computer labs as opposed to having students bring their own devices.

CONCLUSIONS

Through our research, we have found that there is a large potential for financial savings by increasing energy efficiency. Across ACU, our pilot campus, we have estimated thousands of dollars per year in savings. Based on these findings, other universities or businesses may also have the potential for drastically reducing their energy costs. However, there are still many challenges that must be addressed, which is the focus for our future research. Of particular interest to us is the development and implementation of a web application that will provide an interface for universities and other organizations to enter their lab parameters in order to easily estimate their own energy usage.

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