A Review of Energy Efficiency Initiatives in Post-Secondary Educational Institutes

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***Abstract*—In this paper, a review of the steps taken by some of the higher educational institutes around the world to increase their energy efficiency is presented. The paper also provided an overview of the state-of-the-art in managing energy consumption in computers. With the growing number of computers being employed in higher educational institutes, this paper discuses and present an example on how power management in computer labs and IT centres can help educational institutes improve their energy efficiency and carbon footprint.**

***Index Terms*—Energy efficiency, computer power management, educational institutes.**

I. Introduction

The warming of the climate system is one the first main challenges of the twenty-first century. It has been argued that most of the observed increase in global average temperatures since the mid twentieth century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations [1]. Thus, rising up to the challenge of climate change demands an effort from society to reduce greenhouse gasses (GHG) emissions using new ideas and tools to achieve sustainable development.

Universities constitute a suitable target for environmentally friendly initiatives. Universities and colleges are usually attended by young people who consider environmental issues important to their lives [2] and are ready to accept changes. Due to the rising utility costs that dwarf the annual rate of inflation, post secondary education institutions are open to new sustainability programs that tackle the ever-escalating energy expenses [3]. The size of the potential target audience also is an important reason for focusing in such educational institutions. In Canada and the United States alone, there were approximately 20 million students enrolled in 2007 [4] [5]. This is roughly the equivalent to the population of the whole Scandinavian Peninsula as of 2010 [6]. One way to reduce global GHG emissions is improving energy efficiency of small and extremely ubiquitous office equipment, such as computers, as the number of personal computers is expected to reach 2 billion by 2014 [7]. A significant portion of those billions of computers is located in post secondary educational institutes. Assuming that there is 1 computer per 10 students, as it is the case at the University of Calgary, Canada, there will be more than 2 million energy-hungry computers in North American universities and colleges alone. On average, and when kept on for the whole year, a desktop computer with a LCD monitor uses approximately 475 kWh a year [8]. Two million computers will consume approximately 950 MWh a year, producing close to 665,000 metric tons of CO2 [9]; this is roughly the same amount of CO2 emissions from 130,000 typical passenger vehicles [10]. Even a reduction of only 10% will have the same impact as taking 13,000 vehicles off the streets. Thus, there is a significant potential untapped for reducing GHG by improving current usage strategies of computers in higher education institutes.

In the present paper, efforts on improving carbon footprint of higher educational institutes are reviewed. The review is focused mainly on what universities are doing to increase the efficiency of buildings. This paper also reviews the approaches to reduce energy consumption including behaviour-oriented energy conservation programs, student-led initiatives and various retrofits to increase energy efficiency in university buildings. This paper also discusses a power management-based strategy for saving energy consumed by computers in post-secondary educational institutions. The results of preliminary ad hoc power management schemes provide incentive for using data mining and artificial intelligence-based strategies for power management in universities' computers.

The remainder of this paper is organized as follows: in Section II literature on energy approaches in higher educational institutes is reviewed, including approaches to reducing energy consumption such as behaviour-oriented energy conservation programs, student-led initiatives and various retrofits to increase energy efficiency in university buildings. Section III includes a review on available literature on computer-related energy consumption as well as studies on the impact of power management schemes in computers. Section IV presents the current state of affairs in the University of Calgary's computer labs as well as some preliminary results on estimated savings using power management. Section V includes the conclusions of the paper.

II. Energy efficiency improvements in higher education institutes

Universities across the world are being faced with highly increasing utility costs, which serve as a motivation for boosting up their efforts to save money. Currently, those efforts are headed towards developing new sustainability programs

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to tackle the escalating energy expenses; however the goal of these projects is not only the containment of utility costs but also a reduction of the environmental footprint [11] [12] as can be inferred from the signing of the “President’s Climate Commitment” by over 600 US college and university presidents [13].

The continuously growing energy budgets are forcing many university presidents to make hard decisions on how to keep the institution financially afloat. Options include cutbacks in building maintenance and postponing the building of new classrooms and laboratories, as well as postponing the update of existing facilities [14]. Fortunately, there are other approaches making their headways across universities. If an institution wants to reduce utility expenses, it can do so by adhering to LEED standards, establishing programs to reduce transportation cost, promoting energy conservation schemes among staff members, faculty members and students and also making sure that any new building is energy efficient.

Designing and constructing energy efficient buildings have the potential to reduce or eliminate negative environmental impacts. Once the building is constructed, operating costs are reduced, worker productivity and comfort are increased, all of which result in an enhancement of the building marketability [15]. All of these propositions mean that the construction of an energy efficient building has environmental, economic and social benefits for building owners, occupants and the general population.

Sustainability involves improving the environmental, economic and social impacts of resource use. The most common target when developing a strategy to fight climate change is the reduction of greenhouse gas (GHG) emissions. This requires much more than just technological change; it demands behavioural change and adaption from the community and long-term commitment.

Any university aiming to reduce GHG emission must take into account the fact that a behaviour-oriented energy conservation program, in addition to various system upgrades is essential to a comprehensive energy reduction effort. Any kind of measure is insufficient to reduce energy consumption by itself if the building’s occupants are not actively engaged in the process [16].

One of the universities to implement such behaviour-oriented energy conservation programs is the University of Michigan (UM), an institution encompassing over 200 buildings, with over 41,000 students and 20,000 faculty and staff members. Since the late 1980s, UM has made efforts to reduce rising energy costs focusing on building modifications and retrofitting measures. In 2006, UM officially decided that it was necessary to go beyond the technological approach of the last 25 years. A pilot study was planned and conducted to examine the behavioural aspects of energy consumption among faculty, staff and students. The purpose of the study was to determine energy consuming practices and attitudes on campus and thus help university administrators to establish more effective policies [14]. The findings of the pilot study at the UM showed that a significant proportion of the faculty, staff and students were unaware of UM efforts to reduce energy consumption on campus. These poor results concluded that UM should launch a publicity campaign aimed letting everyone know of the concerted efforts of the university to reduce energy consumption in buildings by establishing clear energy reduction targets. Finally, the pilot study led to a more comprehensive understanding of how attitudes may affect energy conservation behaviour at a large educational institution and can also serve as a model for using behavioural research into energy consumption reducing efforts in universities around the globe.

In the fiscal year 2005/2006, the University of Calgary (UofC), emitted 214,733 metric tones of CO2 caused by its buildings operations. By identifying the best options in energy supply, energy conversion and distribution, and by using state of the art technology for energy sustainability for buildings, the UofC planned to have reduced 15% in utility budget costs by March 2009 [17]. Since 1995, the Energy Performance Initiative has been responsible for the use of lighting controls, variable air conditioning, occupant awareness dashboards and lighting retrofits. These upgrades resulted in the reduction of 8,100 metric tones of CO2 per year over the past 14 years. The medium term objective of this project is to meet the Kyoto Protocol target of reducing gas emissions 6% below 1990 levels and also to achieve LEED accreditation. The backbone of this project is the implementation of a cogeneration plant, which produces electrical power and thermal energy from a single energy source: in this case, natural gas. This would result in an increase of gas consumption by 20%, being the extra fuel required to run the turbine engine, and the reduction of electrical energy purchases by 50%. Although the UofC is among the top universities in Canada implementing sustainability measures, more emphasis must be placed on bringing the community together to work for this project. This should not be a project just for professors and students, but also for staff and even visitors, because all the efforts might lead to a poor results if there is no sufficient cooperation between the 40,000 people that currently work, live and study and the UofC.

The University of British Columbia (UBC), Vancouver, Canada, implemented the three-year project ECOTrek from 2003 to 2006. The main objective was to reduce energy consumption, water use and GHG emissions by retrofitting 300 academic buildings. The project resulted in reductions in energy consumption of 20%, water use reduction of 30%, a reduction of 15% in GHG emission and savings of 2.6 million dollars annually [18]. These results were achieved by using a Building Management System to automate 90% of the academic campus HVAC systems, to match performance to the exact occupancy of any given building. However, more work still must be done to show people what the university is doing and what they can do to help.

At the Polytechnic University of Catalonia (UPC), in Spain, a plan for sustainability in 2015 was drafted to achieve a change in mentality and behaviour of the academic community. This means putting more effort in social commitment

TABLE I
SOME OF INSTITUTIONS OF HIGHER EDUCATION IN THE USA WITH GREENHOUSE REDUCTION TARGETS

Institution	Commitment	Date of Commitment
Bowdoin College	11% below 2002 levels by 2010	January 2006
College of the Atlantic	Zero emission, effective immediately	October 2006
Cornell University	7% below 1990 levels by 2008	April 2001
Michigan State University	6% below 1998-2001 baseline by 2010	November 2006
Tufts University	7% below 1990 levels by 2012	April 1999
UNC at Chapel Hill	10% below 2005 levels by 2015; 20% by 2030	June 2006
Williams College	10% below 1990-91 levels by 2020	January 2007
Yale University	10% below 1990 levels by 2020	October 2005

Source: Association for the Advancement of Sustainability in Higher Education [20], [21]

to reduce UPC's carbon footprint instead of achieving high amounts of resources to retrofit a large number of buildings. The plan also includes the effort to secure money for research to identify the main factors that determine the inefficient consumption of energy in campus[19]. The UPS's Plan puts more focus on people instead of technology, which is a different paradigm from that of the aforementioned universities. Although there are no clear results of this plan yet, it will be interesting to follow because it might give a hint on what more can be done without spending millions of dollars on new technology.

Another adopter of a GHG reduction policy is Yale University, in the United States, which in 2003 set a goal of reducing its GHG emissions by 10% below 1990 levels by 2020. Yale's intention is to avoid falling into the trap of overreaching system modifications and instead focus on specific projects with a smaller number of participants and a less ambitious set of goals, which is often more successful [22]. In order to have a successful strategy to attain sustainability goals, Yale's GHG reduction target is part of a five step process: development of a vision, development of quantifiable goals, leadership endorsement, implementation and an institutional evolution towards a sustainable campus. Yale has identified that almost 90% of its GHG emissions come from purchased electricity and the two on-campus power plants, and plans to reduce these emissions by focusing on efficiency upgrades and renewable energy projects, instead of purchasing carbon offsets [20]. As of 2008, Yale had reduced is GHG emissions by 7% below 2005 levels, and has achieved LEED accreditation in 10 buildings. Although the project in Yale looks promising; it seems to rely too heavily on technology instead of people involvement in a project, which is something critical for any successful sustainability project.

The University of New Hampshire (UNH), in the United States, is among the pioneers in reducing energy consumption in educational institutes in America. For more than 35 years it has cultivated a sustainability outlook in its students integrating sustainability into the spirit of an institution of higher learning in order to cultivate a critical and creative global sustainability outlook in students, staff and faculty members [23]. The UNH approach to reduce GHG emissions is to calculate them by using a greenhouse gas inventory tool, developed by the UNH and marketed as the "Clear Air-Cool Planet Campus Carbon Calculator". This translates to a decrease of GHG emissions, and an increase in monetary savings for the campus.

The most ambitious project the UNH has taken so far to reduce its carbon footprint was the 2006 installation of a landfill gas pipeline to fuel the on-campus cogeneration heat and power plant, thus making heating/cooling and electricity no longer the largest contributor of emissions. With an initial $28 million investment, the plant has an anticipated payback time of 20 years and resulted in 21% emission reduction in the academic year 2006-2007 compared to the academic year 2005-2006. Another novel step the UNH has taken is to solicit everyone in the university community to come up with new ideas for projects, discuss targets and timelines. The UNH plan incorporates both state-of-the-art measures to reduce GHG emissions, but it also relies heavily on people and their actions [24].

Table I lists the USA institutions of higher education that were early adopters of greenhouse reduction targets, their commitments and dates of commitments.

There is also a variety of student-led initiatives to reduce energy consumption and fighting climate change in universities around the world, ranging from the use of renewable energy [25] to reducing GHG emissions using energy efficient equipment and energy efficient buildings [26]. The most common type of student-led initiative is focused on awareness-raising, providing students with real options for taking personal action to reduce their impact on the environment. Usually the core of these awareness-raising campaigns is a weeklong series of events to send a message to the student body about the importance of sustainability. Another type of student-led initiative is residence buildings competitions to reduce electricity consumption. This initiative proved to be the most compelling for students; the winning campus was able to incorporate 46% of students living on campus and achieved a reduction electricity consumption of 4%. An additional benefit of this competition is that it provided a new impetus to install energy meters in residences and a high level of institutional involvement was achieved at the participating universities [27]. Students are key players on campuses and have a unique perspective that is helpful to any type of discussion around campus climate solutions, this discussion should have in mind that the best option for encouraging young leadership in creating climate solutions on campuses is a shared power relationship, since the student body will implement many of the initiatives in residences and in their student union.

III. Current energy consumption in computers and related work

Since the introduction of the personal computer in the 1980, the growth in the market for this particular device has been remarkable. It was only until 1992 when the Environmental Protection Agency launched the Energy Star program, that computers among other electronic product and appliances started being tested and labeled for energy efficiency [28].

In order to improve energy efficiency, Energy Star labeled computers and electronic devices use power management (PM) schemes, in which products enter a low power state after a certain period of inactivity, saving energy. In computers, the period of inactivity that triggers a transition to a low power state can be customized by the user. Since PM parameters are customizable, a user can potentially drive energy savings down to zero.

The University of California, in Berkeley, conducted an after-hours survey in office, education and health-care buildings with the objective of collecting power data on a 1,453 desktop computers during 4 hours [29]. The results indicated a mean turn off rate of 36%, that varied from building to building. A mere 6% of the computers had a PM scheme in place. As for LCD monitors the average turn off rate was 32% with a 75% PM-on rate, however, the monitors needed a signal from the PC to enter a low power mode. The study reports that university buildings have the highest monitor PM rate, 87% but at the same time, monitor turn off rates were the lowest, 13%, in university buildings. The lack of an automated collection of data is responsible for making the study look like a snapshot of the problem. It is desirable to have a more extensive set of data over the time, which will show possible seasonalities.

The relationship between the user and the PM rates were studied by the Lawrence Berkeley National Laboratory. In this study, the information was collected using after-hours audits in non occupied commercial buildings, since they have relatively fixed schedules. The audit consisted in physical inspection of the power cord of the computer [30]. Not surprisingly it was found that PM influences energy use to a great extent, and also that the relationship between user behaviour and on/off modes is very straightforward. If somebody is using the device, it is on, otherwise, it is off. Background network activity may keep a computer from entering a low power mode, and if the computer enters a low power mode, it may fail to interact correctly with the network. In this case, the PM is disabled.

A PM scheme has to wait for a certain period of time of inactivity. The average PM delay time was found to be 15 minutes. Four scenarios were evaluated in [30]: as-found, computers always on but with PM in place, computer turned off after hours without PM in place, and finally, computers turned off after hours and with PM in place during the day. It was also found that PM rate depends on corporate culture which varies in different types of industry. Total energy consumption by a computer was calculated under each scenario. The first one constitutes 100% of consumption over a year. The second scenario, consumed only 52% over the same period, the third scenario consumed even less, 20% and finally, the fourth and most aggressive scenario takes consumption down to 17%. The same calculations were done for a LCD monitor under each scenario. Again, the first one constitutes 100% of consumption over a year. The second scenario, consumed only 22% over the same period, the third scenario consumed even less, 21% and finally, the fourth and most aggressive scenario takes consumption down to 17%.

These results must be taken cautiously, since they are based on a commercial building with more strict hours of operation, compared to a post secondary education institute where classes can go until 10 p.m. However, they provide a good argument to increase the implementation of PM successfully to attain energy savings. Weekends and evenings make up 75% of the week. In the average office space with a 35 hour work week, a computer that is on 7 hours is in active use only for 3 hours [31], the remaining time, it is idle and wasting energy.

In another study, the Lawrence Berkeley National Laboratory analyzed the relationship between consumption of energy and power on 14 desktop computers [32]. Computers and monitors have many levels of activity. A computer can be on-idle, which means that it is not running any process and thus the processor can be stop. Another mode of operation is on-active, when the computer is performing calculations. Hibernate is not a mode itself, but a process in which the computer saves the current state of the system into the hard drive, and then, the computer shuts itself down. Energy consumption was measured for every power mode using a power line meter. For desktop computers, it was found that they consume on average 3W when turned off, and an average of 9W when in sleep mode. Also, the average recovery time from sleep mode was close to 10 seconds. For monitors, it was found that their consumption is 2W on average both for when turned off and in sleep mode, and also, monitors require 2 seconds recovery time.

As mentioned before, any PM scheme requires time to enter a sleep state and also to recover itself from it. This amount of time will obviously have an impact on energy consumption. A study was conducted on this subject and it found - via surveys and field measurements - the relationship between the delay time and the average rate of PM [33]. The lower rate of use and the shorter delay time will result in a higher rate of PM operating during idling. For a time delay of 5 minutes, the PM rate was 76.3%, whereas for a delay of 60 minutes, the PM rate was 19.6%.

IV. Strategies for saving energy in computer labs: the example of the University of Calgary

The University of Calgary, Canada, with over 30,000 undergraduate and graduate students it is currently ranked as one of Canada's most sustainable universities by the College Sustainability Report Card 2011 [34]. The Information and Communication Technology, ICT Building at the University of Calgary has three Windows-based computer labs totalling 64 desktop computers. Each computer has the same make, the CPU consumes 50W idle, 2.9 W in sleep state and 0.7W

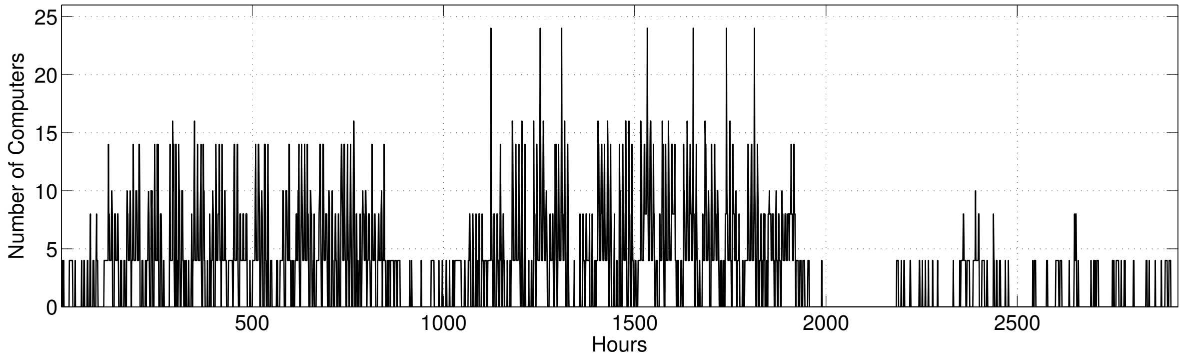

Fig. 1. ICT217 Computer Lab Usage September 2008 - August 2009

when it is off. As for the LCD monitors, they consume 22 W when used, and their consumption goes down to 0.4 W when in stand-by mode. Currently, the computers inside ICT building are never turned off as part of the IT policy in place. The rationale behind this is that the computers must be on so that they have immediate access to the latest security updates. Also, as part of the security policies of the U of C, every time a user logs in and logs out of a computer located inside a computer lab, a timestamp is recorded.

The timestamps recorded for those three labs from September 1st 2008 to August 31st 2009 were analyzed. Using the timestamps, the number of working computers in each minute of a full year was obtained, as shown in Fig. 1. Seasonalities are very clear, there are peaks and valleys and long periods of no computer use. Peaks are related to examination periods. Valleys are related to special periods such as the beginning of the semester, a no classes 1-week period and December holidays. After the Academic Year ends, the Spring/Summer term begins. During this particular period, computer usage drops dramatically since most of the undergraduate students are on vacation. Most of the usage thus can be attributed to graduate students. It is clear that using even a simple power management scheme would results in significant savings for the U of C. Three simple strategies are proposed based on common sense of the behaviour of computer labs over an extended period of time.

Under Strategy 1, all the computers inside the lab are kept on from 06:00 to 24:00, during the remaining 6 hours the computer would be in a deep sleep state. Strategy 2 is takes into account the fact that the computer usage patterns are not the same during weekdays and weekends. During the weekdays, computer labs are controlled using Strategy 1; however during the weekends, a new strategy is used. On Sundays, only 50% of the computers are kept on from 10:00 to 18:00; all the computers in the lab remain in the deep sleep state for the time remaining. On Saturdays, 50% of the computers are kept on from 06:00 to 18:00; after that time all the computers in the lab remain in deep sleep state.

Strategy 3 takes into account different patterns during the week and also seasons. During Fall and Winter it is expected that the number of computers in use will be higher than the number of computer in use during Spring and Summer. Strategy 2 is implemented during September 1st and April 30st. From May 1st until August 31st a new strategy is used. From Mondays to Saturdays, only 50% of the computers are kept on from 07:00 to 19:00; all the computers in the lab remain in the deep sleep state for the rest of the time. During Sundays, 50% of the computers are kept on from 10:00 to 18:00; all the computers in the lab remain in the deep sleep state for the rest of the time. Each strategy is simulated over the same 365 days period for each computer lab and then compared with the current 24/7 PM policy in place. Table II provides a comparison between all of them for each computer lab. It is easy to see that as the complexity of the strategies increase, so does energy efficiency for the computer labs.

The analysis of the gathered data shows that data mining and machine learning approaches can potentially generate PM schedules that improve efficiency computer labs significantly. Those approaches are under investigation and will be reported in future publications. It is important to ensure that sophisticated PM strategies are feasible. There is a need for balancing energy savings with the comfort level for students and acceptable security measures for IT operators.

	ICT217	ICT318	ICT320
Current Policy	11,355 (100%)	11,270 (100%)	7,590 (100%)
PM Strategy 1	8,740 (77%)	8,670 (77%)	5,850 (77%)
PM Strategy 2	7,100 (62.5%)	7,040 (62.5%)	4,760 (62.5%)
PM Strategy 3	5,700 (50%)	5,640 (50%)	3,830 (50%)

TABLE II
COMPARISON OF ENERGY CONSUMPTION (IN KWH) OF THE THREE SIMPLE PM SCENARIOS WITH THE CURRENT PM POLICY

V. CONCLUSION

This paper presented an overview of the ongoing efforts in some higher education institutes with regard to energy efficiency and conservation. The available reports point that while technological improvements and retrofits can potentially improve energy efficiency is such institutes, awareness programs to engage the students, faculty and staff in those programs are key in obtaining acceptable results. Also reviewed in this paper is the potential for energy conservation in computer labs in higher educational institutes. With more than 20,000,000 in North America, and the typical one computer for each 10 student norm, the potential for energy conservation in computer labs and IT centres is significant.

An example of three simple power management schemes based on the data from typical computer labs at the University of Calgary was reported in this paper. The results show that with very naive solutions, energy consumption and emissions in computer labs can be cut by up to 50%, from an estimated 8 metric tons per computer lab during a year. Extrapolating the results, just by changing the current power management schemes in the computer labs, the UofC would stop emitting 495 metric tons of CO2 which has the same effect as taking approximately 95 cars off the streets. This would result in a smaller carbon footprint for the UofC, a boost for its sustainability credentials and a reduction in utility costs.

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