# Shut off and Save

## An Analysis of Energy Use and Environmental Impact of Dalhousie Studley Campus Computers

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## Abstract

Fossil fuel emissions are currently described as the main cause of global warming. This is a result of energy use and is of particular concern when energy is wasted, therefore results in unnecessary emissions. This study focused on energy waste on Dalhousie University campus pertaining to computers left idle in the Marion McCain Arts and Social Science student computer labs. Four research methods were utilized; literature review, interviews, observations and student surveys. Observations over a two week period indicated that 71% of the computers were left on and not used by students. This resulted in the combustion of 7.92-19.80 metric tons of coal and the emission of 20.49-51.23 metric tons of $CO_2$, 49.91-124.76 kg of $SO_2$ and 50.90-127.26 kg of $NO_2$. As well, it is costing Dalhousie University between $1396.14 and $3490.35 per eight month academic term. Student surveys indicated that students would be willing to turn the computers off after each use and this would not alter their time spent in the labs. As well, students believed that leaving computers idle was harmful to the environment. Recommendations to Dalhousie University included a “shut-off” program where the start menu would only allow students to “shut-off” in order to exit their user account. Decreasing the number of computers made available to the students during weekends and non-peak hours by closing certain computer labs was also suggested. Suggested areas for future research included an expanded observation period to include the summer and the exam periods, as well as the comparison of labs across campus. Further research into computer technology regarding “shut-off” and energy saving software is advised. Finally, measurements regarding the quantity of energy consumed by idle computers should be further investigated to increase the validity of the study.

# Introduction

## Background and Setting

Burning fossil fuels has detrimental effects on the environment. Global climate change is one such effect that is evident around the world today. The rising demand for fossil fuels has a direct impact on climate change because of the large amounts of carbon dioxide ($CO_2$) released into the atmosphere during the burning process (Montague, 1999). Parallel to the increase in energy demand is the increase in the use of computers, which has been on the rise in institutions, companies and in homes. This increased use of computers has resulted in higher energy consumption. This energy consumption from computers accounts for approximately 10% of all commercial energy production (Energy Management, 2004). Much of the energy consumed by computers takes place while the machine is idle and is thus avoidable by turning off computers when they are not in use.

Research shows that this unnecessary energy consumption is due to the major misconceptions of today's computer users. One such misconception is that screensavers reduce energy consumption. Screensavers use as much energy as the computer does running at full capacity (Energy Management, 2004). Another common misconception is that it is harmful to the computer if it is repeatedly turned on and off. In fact, the opposite is true; the life span of a computer can be lengthened by turning it off when it is not in use (Energy Management, 2004; Adcock, 1995).

A typical computer uses between approximately 120 and 300 watts (Energy Management, 2004) of energy when idle at an average cost of $0.65 per kWh (O'Hara, 2005: Appendix 1). When a computer is left on all day it can consume a notable quantity of energy within the course of a year. If an institution has numerous computers left on all day the energy consumption is even greater. Therefore, by eliminating the ways that energy is consumed needlessly, such as when a computer is not being used, energy consumption, as well as energy costs, can be greatly reduced.

This study aims to reduce this excessive use of energy by investigating the feasibility of turning off each computer when it is not in use on Dalhousie campus. Since 90% of electricity in Nova Scotia is derived from coal, which is a major contributor to global climate change (Nova Scotia Power, 2005). This reduction would decrease the negative impact on the environment. Along with the environmental benefits, the university could also see reductions in economic costs associated with energy consumption. The following report will discuss this study in detail by examining the specific problem, the methods used to address this problem, and the possible solutions obtained from the results.

## Problem Statement

There are approximately 800 public computers available to students at Dalhousie University (Appendix 1). Many of these computers are left idle for long periods of time. When these computers are left on but are unused they continue to expend energy. This waste of energy leads to an excess consumption of fossil fuels and thus avoidable energy costs. Also, the unnecessary consumption of fossil fuel negatively impacts the environment.

## Significance of Problem

Consuming energy, where it could otherwise be avoided, is a significant problem due to the negative impacts on the environment and financial loss. Therefore, any investigation of how energy consumption can be decreased is worth exploring. The knowledge gained from this project will be applicable in many different locations across the Dalhousie campus, as well as at other Canadian universities and institutions. Though the results that were obtained in this study are not the same as those obtained elsewhere due to the varying number of machines and manner in which they are operated, the principles still apply. The investigation of whether or not there is energy loss from idle computers will provoke other institutions to examine their own facilities because of the potential to save energy and money. This investigation and the suggestions for possible solutions to the problem have the potential to be used on an institutional or personal level, which can affect change on a large scale. This means a substantial decrease in energy consumption would decrease spending and benefit the environment.

## Objectives of the Study

### Nominal Objectives:

- To determine how much energy is being wasted as a result of computers that are left on but not being used, during the computer lab hours of 8:00 AM to 10:00 PM on weekdays and 8:00 AM to 6:00 PM on weekends.
- To determine how wasted energy on Dalhousie campus affects the environment.
- To determine how much money could be saved if the computers were shut down when they were not being used.

### Operational Objectives:

- To determine the number of computers there are in the Marion McCain Arts and Social Sciences building (FASS).
- To determine if there are computers being left on but not being used in the FASS.
- To conduct an interview with those responsible for shutting down the computers to establish how frequently and efficiently the task is performed.

- To conduct a survey of those who use the computer labs to establish their views on the computer labs in the FASS.
- To determine how much energy a computer wastes when it is on and not being used.
- To determine the quantity of carbon dioxide, sulphur dioxide, and nitrogen dioxide released into the atmosphere due to energy use by idle computers
- To determine the financial impact as a result of the energy consumed to run idle computers.

## Definition of Terms

**Building of interest**: the building on Dalhousie campus in which the computer lab under investigation were located. This building is called the Marion McCain Arts and Social Science building (FASS).

**Computer**: the computer tower, the monitor and all other peripheral components excluding printers and scanners. The computers used by students found in the computer rooms, excluding private computers such as professors’ and departmental computers.

**Computer labs**: a room containing three or more computers which are accessible for use by Dalhousie students.

**Dalhousie campus**: the area of Studley campus, enclosed by Robie St., South St., Oxford St. and Coburg St.

**Computer energy waste**: the quantity of energy (watts) consumed by an idle computer

**Energy Star**: "…a United States government backed program helping businesses and individuals protect the environment through superior energy efficiency." (Energy Star, 2005)

**FASS**: Defined as an acronym, which stands for the Faculty of Arts and Social Sciences building, officially known as the Marion McCain Arts and Social Sciences building.

**Full power**: a computer turned on without a screen saver running

**Hibernation**: "very similar to standby, but instead of writing the state of the machine into memory, it copies the hard drive and shuts the machine off completely" (Magid, 2001).

**Idle**: the computer being left on at full capacity but not being used.

**Log off**: exiting from a Dalhousie computer network account.  The computer remains on but the user’s account becomes inaccessible to others.

**Power off**: a state of a computer when the hard drive and monitor are turned off

**Sleep mode**: a state of a computer that can be of two types: either standby or hibernation.

**Standby**: a state of the machine in which programs that are running are stored in memory and copied to an area of the computer’s memory. “The hard drive, monitor and other components are turned off but a very small amount of power is used to keep the memory alive so that it can store the data it needs when the machine wakes up." (Magid, 2001).

**Weekdays**: the hours from Monday to Friday that Dalhousie students are permitted in the computer labs.  The computer labs in the FASS are open from 8:00AM to 10:00PM Monday to Friday.

**Weekend**: the hours on Saturday and Sunday that Dalhousie students are permitted in the computer labs.  The computer labs in the FASS are open from 8:00AM to 6:00PM Saturday and Sunday.

## Literature Review

Among the many existing problems in the world today, global climate change is on the rise. It is an important issue that deserves much attention. Global warming directly affects the planet and therefore has a direct effect on people. The greenhouse gas effect is a natural process and without it the Earth would be covered in ice (Montague, 1999). Over the past few hundred years, humans have increased the rate at which the Earth's climate is changing due to increasing greenhouse gases being emitted into the atmosphere. The burning of fossil fuels (coal, oil and natural gas) plus deforestation have increased the atmospheric $CO_2$ by 31% (270 parts pr million (ppm) - 360ppm) during the past few hundred years (Montague, 1999). The combustion of fossil fuels combined with deforestation, adds an estimated 7.7 billion tons of $CO_2$ to the atmosphere annually (Montague, 1999). The evidence of global climate change can be found in various places around the world. For example, Alaska is an average six degrees Celsius warmer than it was 35 years ago. Areas which were once carbon sinks, such as the arctic tundra, have begun a process where the ice begins to melt and they begin to emit $CO_2$ in a positive feedback loop. With many factors contributing to the $CO_2$ emitted into the atmosphere, every reduction is helpful in the struggle to reduce carbon emissions.

This is where the issue of energy wasted by idle computers can be recognized. Energy consumed by idle computers is a problem often ignored by the average computer user (Sperg, 1991). Computers currently consume an estimated 10% of all commercial energy consumption (Energy Management, 2004). Depending on the energy source used, the environmental consequences of wasted energy will vary; however, unless energy is produced from renewable sources, decreasing energy consumption will reduce environmental damage and decrease the fossil fuel emissions (United States Department of Energy, 2004).

Past studies have indicated many public misconceptions about computer energy use.  Screensavers, which are often wrongly assumed to reduce energy consumption, typically consume as much energy as a computer running at full capacity and are only intended to protect the phosphorescent coating on the inside of the screen (Energy Management, 2004). Secondly, there is a common misconception that turning a computer on and off will shorten its life span. Research has shown that the opposite is the case. A computer's life is established by the amount of time it is running, and turning it off for even short periods of time is beneficial to its lifespan. (Energy Management, 2004; Adcock, 1995).

Researchers have performed many studies that have shown that substantial quantities of energy could be saved by reducing the amount of time that computers are left on and idle. When equipment is shut down, it generates less heat, collects less dust, and reduces mechanical stress which allows the machine to have a longer and more reliable life (Tufts Climate Initiative 2005). Typically, institutions that have implemented these recommendations experienced substantial monetary benefits while benefiting the environment through reduced electricity use.

Along with the research conducted on the benefits of turning off computers it was also discovered that students were not actively participating in the process of saving energy. In a study conducted by Tufts Climate Change organization at the University of Maine, it was found that during the fall semester of 1999, 80% of students were leaving their computers on ‘always’ or ‘nearly always’ (Tufts Climate Initiative 2005). Also, the computers in the labs were being left on all day and all night. They calculated that the average desktop computer used 120 watts and that by implementing an efficient program of turning off their computer the university could save a moderate amount of money (Tufts Climate Initiative 2005). They also concluded that student participation was absolutely necessary for the program to operate efficiently.

A study was done at a university in New Zealand in 1995 because energy use had been steadily increasing in the previous ten years (Adcock, 1995). 469 computers in a commerce building were monitored over one academic term. It was shown that a large quantity of money could be saved if computers were shut off while not in use and if all Energy Star components available were activated. Although 37% of the computers monitored had Energy Star components installed only 12% were activated. Adcock found that $4000 could be saved by educating users about energy loss, negative effects, activating all Energy Star components and installing an automatic power management system on machines which were incompatible with Energy Star (Adcock, 1990). Energy Star software allows machines to automatically enter sleep mode, which uses fifteen watts or 70% less energy than a computer running at full capacity (United States Department of Energy, 2004).

The University of Michigan conducted a similar study, with an estimated 26,800 computers located on the campus (Energy Management, 2004). The university calculated that personal computer (PC) operation alone cost an estimated $ 1,862,064 in energy costs and 12.4% of the total energy costs of the university annually (Energy Management, 2004). Assuming a typical PC uses 300 watts and is left on for 24 hours per day, everyday, this would result in an annual fee of $200. By simply leaving the computer on for 40 hours per week this figure could be reduced to $50 annually (Energy Management, 2004). Depending on the amount of energy the computer uses, this figure could vary.

At the University of Michigan recommendations were made to shut the computer down if it was going to be idle for more than sixteen minutes. At this time the energy needed to restart the computer is greater than the energy consumed by leaving the computer on (Energy Management, 2004). Similar to the university in New Zealand, many of the computers possessed Energy Star software, but the functions were disabled. It was discovered that if these programs were activated it would save the university an estimated $1,050,426, or almost 56% of total energy costs (Energy Management, 2004).

Aside from activating programs to reduce energy use by computers, devices have been created to have similar effects. An example of this was a pilot test launched in the head office buildings of the Ontario Ministry of the Environment as a Green Workplace Initiative that addressed the energy wasted by computers while left idle (Caddet Energy Efficiency, 1999). The study involved the 307 computer located in the building and the implementation of "Power Saver", an Energy Star compliant tiny device that plugs into the power cord. The device "does not require connection to any of the PC's data lines, and it does not interact or interfere with CPU, hard drive, modem or network"(Caddet Energy Efficiency, 1999). The results of the study were evident after only a short period of time. Over a twelve month period, the Power Saver devices managed to saved $20,650 (CAD), the devices themselves cost $12,280, therefore the payback period was a mere seven months. The direct energy savings were 68%, 32% of which came from reduced air conditioning.

Along with the monetary benefits of turning off idle computers, researchers have identified environmental benefits. A study in Australia predicted that because of the energy savings, shutting off a single computer for a year would stop 425 kg of $CO_2$ from being released into the atmosphere (Northern Territory Department of Infrastructure, Planning and Environment, 2004). As a greenhouse gas, $CO_2$ stores heat creating a warming effect, resulting in climate change (Tufts Climate Change Initiative, 2004). By reducing the amount of energy used by computers, the amount of $CO_2$ emitted will be reduced and thus lessening the impacts of climate change on the environment.

Current research shows that computers left on while idle waste energy, creating increased cost and pollution. By implementing shutoff programs and installing Energy Star software on existing computers it is possible to mitigate these deleterious effects.

## Methods

This study was designed to determine how the computers on Dalhousie Campus were being used. Limitations for this project included areas such as time constraints and accessibility (Palys, 2003). Time constraints were based on the time frame for which the project was to be completed, as well as the times during which the computer labs were open. Accessibility was limited by some computer labs being closed during the day due to classes being held there. Limitations included the willingness of participants to answer the survey and participants' knowledge of the issue. There were also limitations on the amount of computer knowledge of the researchers and how much could be acquired in the duration of the study. Finally, limitations were apparent when trying to find accurate numbers and variables to incorporate into the calculations.

Researchers delimited the study by focusing the project only on one building on campus and by setting a time frame for observations and administering surveys (Palys, 2003). As well, researchers delimited by collecting data for two weeks in the middle of the semester to avoid exam periods and to have a better representation of the general use. Finally, delimitations also included the amount of time observing was done, due to the schedules of the researchers.

Research tools for this study included various components such as literature review, interviews, observations and surveys. By utilizing these four different methods it increased the validity of the project by providing various qualitative and quantitative measures to ensure each section measured the appropriate variables (Palys, 2003). Reliability was obtained by using easily replicated methods as outlined below and by having observations done over a continuous time frame to provide replications and a general overview of computer use (Palys, 2003).

The literature review included research and obtaining information on other studies with similar objectives. Information was gathered pertaining to past methods used, of values of energy consumed, information on different models of computers, and possible solutions that have been implemented. Information pertaining to energy consumption and greenhouse gas emissions were also located and used to provide information as to the environmental effects of computer use. Literature was obtained from sources such as the library and internet sites of other universities and computer companies. This research method was used primarily to obtain background information and provide education for the researchers. The information obtained included aspects such as potential energy savings and carbon dioxide emissions.

Information pertaining to the computers on Dalhousie campus (number of computers, location, models, energy used etc.) was obtained through a non-probabilistic snowballing technique (Palys, 2003). Telephone and in-person interviews were conducted with open ended questions (Appendix 1) and information as to other contacts to interview was obtained (Palys, 2003). The interviews continued until all the information pertaining to the computers on Dalhousie campus was found.

The building of interest was determined by finding a location which was accessible to the researchers, provided a sample size that would allow for the research to be conducted in the timeframe allotted and represent an area frequented by Dalhousie students on a regular basis, with specific hours set for the use of the rooms. From these criteria it was established that the FASS was the building of interest.

Originally, researchers were to have counted the number of computers left on in the computer room at the closing of each day during the week. Through interviews it was determined that the computers in the FASS were turned on in the evening to allow for maintenance to occur (Appendix 1). The problem being researched was looking at the number of computers that were not being used but were still left on during the hours the computer rooms were open. Data collection of each computer lab was conducted every hour for two weeks including weekends. Times within each hour where rooms were surveyed were determined by a random number generator (Appendix 2). Each computer was surveyed at the designated time and was marked on the data sheets as either on and in use, on and not in use or off (Appendix 3). Observations on each computer were done to minimize sampling error of only sampling a few computers for each lab. As well, the random number generator ensured the times sampled were not subject to any bias by the researchers only going at convenient times. As well it prevented situations of sampling only during class change times. Finally, the two week sampling time frame was determined by the time constraint of the project and to ensure the use of computers throughout each day was represented over a period of time. Once surveys had been completed data was entered onto an Excel spreadsheet and analysis was conducted. Data was compiled and graphs were created representing the number of computers each of the three states. Graphs were separated into weekdays, weekends, by rooms and finally a graph of all times and rooms averaged together was generated. Finally, the number of idle computers was used to determine the amount of energy used, money spent and $CO_2$, $SO_2$ and $NO_2$ emitted (Appendix 5).

Survey sampling was heterogeneous and purposeful by questioning Dalhousie students that frequent the computer rooms being studied (Appendix 4) (Palys, 2003). Questions were designed and ordered so that bias towards environmental issues associated with computers would not play a role in how people were answering the questions (Palys, 2003). Questions were also stated in a direct manner so to decrease potential confusion and help to maximize validity and reliability (Palys, 2003). Surveys were anonymous and were put through ethical review to ensure participant’s privacy was protected (Appendix 6). Researchers administered the surveys outside the computer rooms for one week on Monday at 11:00AM, Tuesday at 1:00pm, Wednesday at 6:00pm and Sunday at 1:00pm for an hour each time. This was done to ensure that people who may frequent the computer rooms at different time were all surveyed. The surveys consisted of closed and structured questions with categorical responses (Palys, 2003). This was to allow for a small range of answers which enabled the researchers to perform comparisons and determine general views on computer use from Dalhousie students (Palys, 2003). Students were approached by the researchers and asked if they could spend a few minutes filling out the survey. The researchers were then in the vicinity while students filled out the survey to answer any questions that may have arisen. This technique was used because it tends to yield a high response rate and provided the ability for clarification needed by the participants (Palys, 2003). As well, it allowed participants to inquire about information regarding the project should they so desire. Survey results were then entered into an Excel spreadsheet. Each question was analyzed by determining the percent number of responses for each option provided. The answer with the greatest percent enabled the researchers to determine how the majority of students felt about the computer use in the FASS.

Possible solutions were then developed to assist in decreasing any problems that were found and recommendations as to how they should be implemented are provided and discussed later.

## Results

Figures 1a-c indicate the mean number of computers turned on and in use, turned on but not in use, and turned off for each weekday hour in the FASS rooms 2018 (Figure 1a), 2019 (Figure 1b), and 2020 (Figure 1c) respectively.

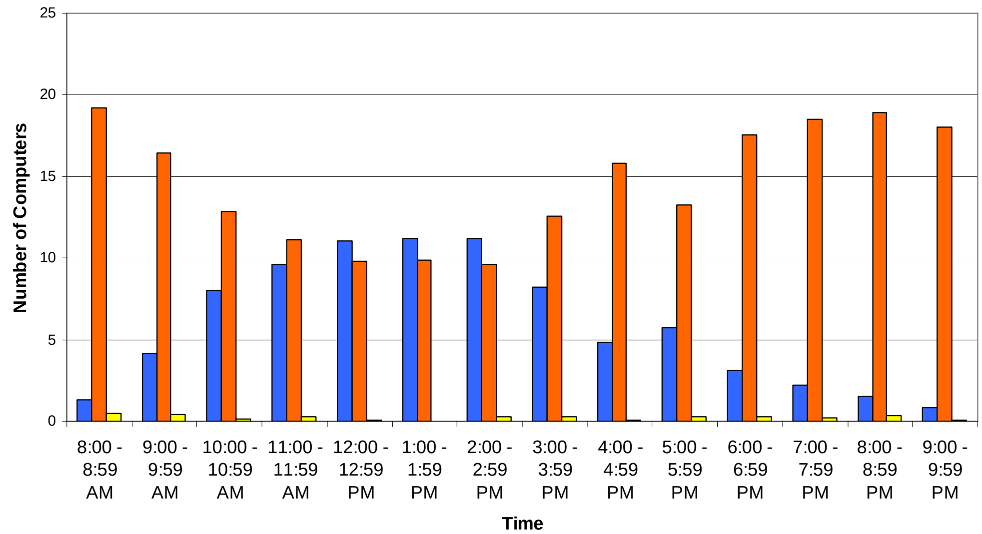


**Figure 1a: Mean weekday computer use per hour in room 2018 of the FASS building**

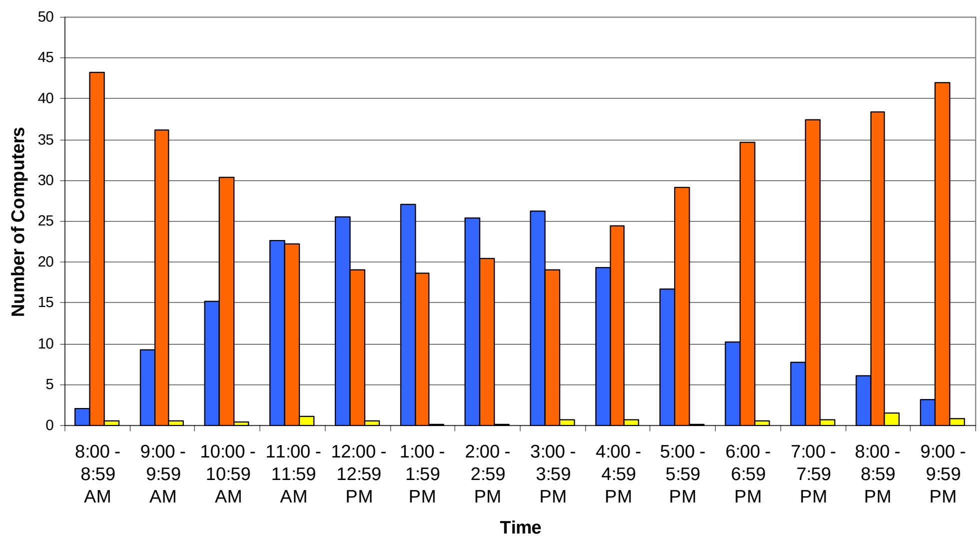


**Figure 1b: Mean weekday computer use per hour in room 2019 of the FASS building**

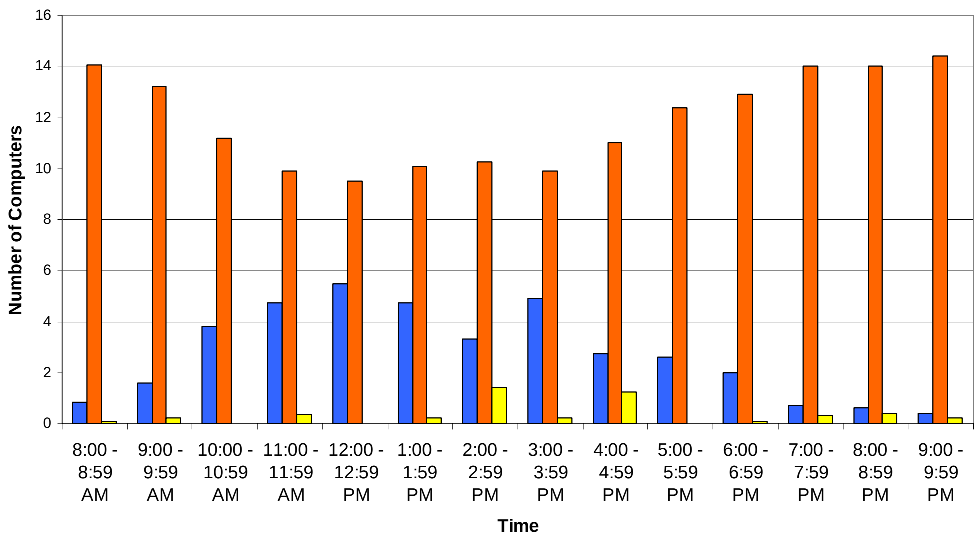


**Figure 1c: Mean weekday computer use per hour in room 2020 of the FASS building**

On average there were only three hours when more computers were on and in use than were idle in room 2018. Room 2019 had four hours when more computers were in use than idle. In room 2020, more computers were idle than in use during all times of the day.

Figure 2 shows the mean number of computers turned on and in use, turned on but not in use, and turned off for each weekday hour in the all of the FASS computer labs combined.

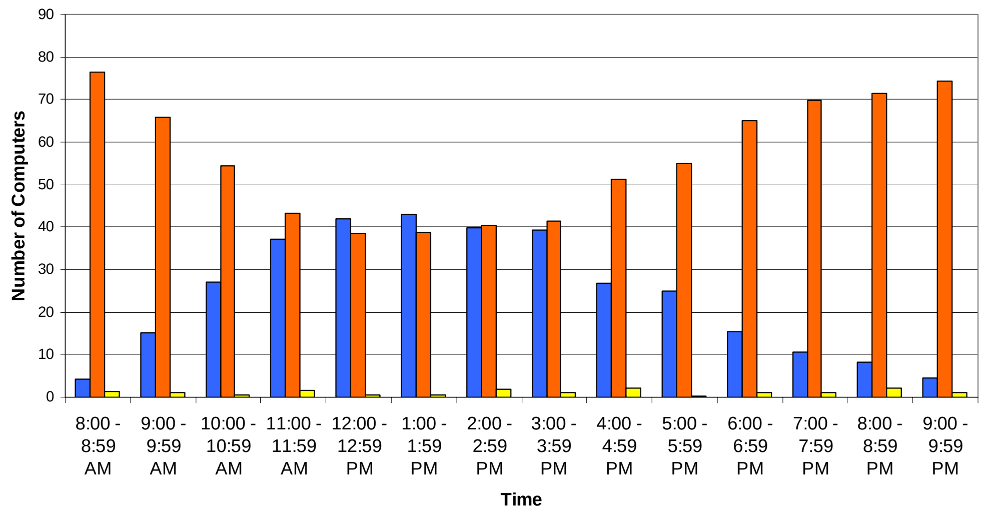


**Figure 2: Mean weekday computer use per hour in rooms 2018, 2019, and 2020 of the FASS building**

Twelve out of the fourteen of the lab hours in a day show more computers idle than in use (Figure 2). There were no time periods observed during the weekdays when a mean of more than 2.25 computers were turned off. On average, during the weekdays, between all the labs, 1.2 computers where turned off at any given point in time.

Figures 3a-c show the mean number of computers turned on and in use, turned on but not in use, and turned off for each weekend hour in the FASS rooms 2018, 2019, and 2020 respectively.

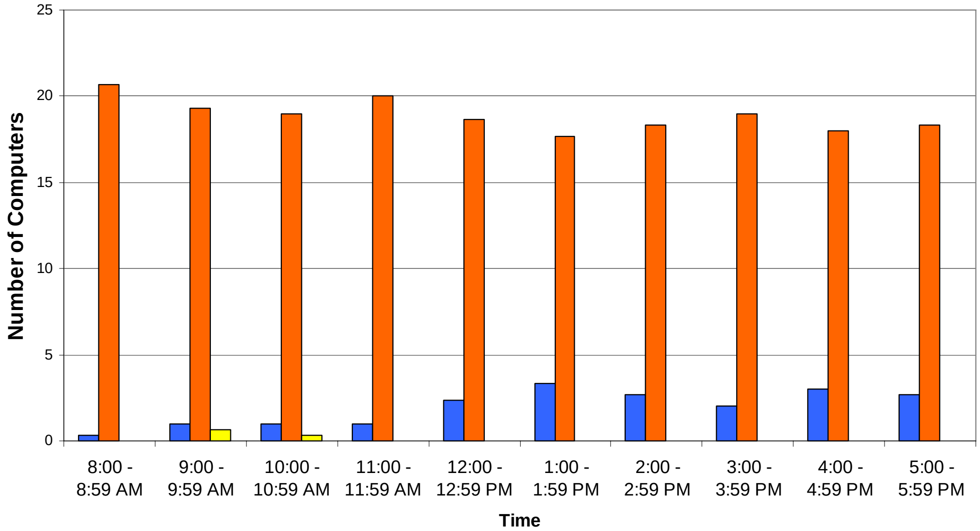


**Figure 3a: Mean weekend computer use per hour in room 2018 of the FASS**

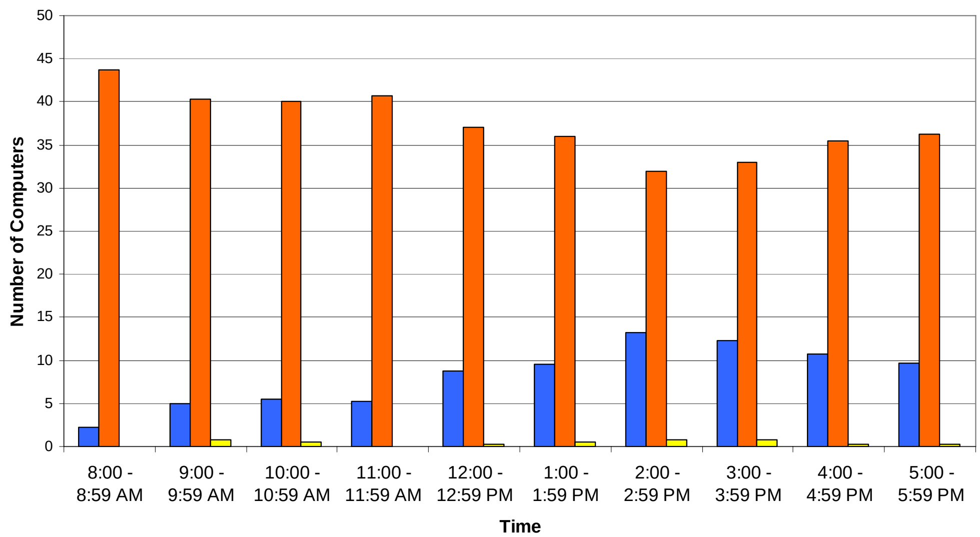


**Figure 3b: Mean weekend computer use per hour in room 2019 of the FASS**

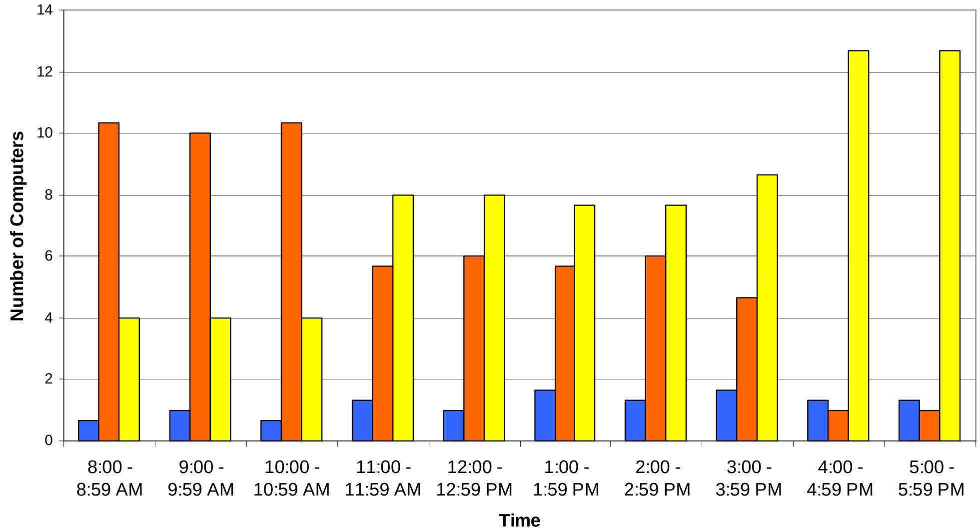


**Figure 3c: Mean weekend computer use per hour in room 2020 of the FASS**

In each of these labs, the mean number of computers idle was always greater than the number of computers in use except for two time periods in room 2020. Peak periods of use were not observed on the weekend.

Figure 4 shows the mean number of computers turned on and in use, turned on but not in use, and turned off for each weekend hour in the all of the FASS computer labs combined. At each point in time there were more computers idle than in use or turned off.

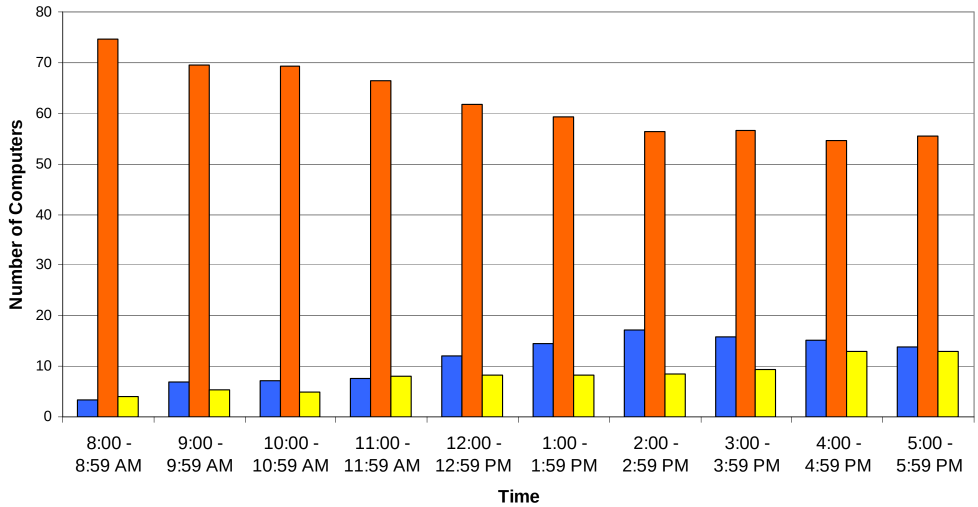


**Figure 4: Mean weekend computer use per hour in room 2018, 2019, and 2020 of the FASS**

Figure 5 demonstrates that, on average, at any given point in time during a week when the computer labs were open at the Faculty of Arts and Social Sciences, 71% of the computers were turned on but not in use, 25% are in use, and 4% were turned off.

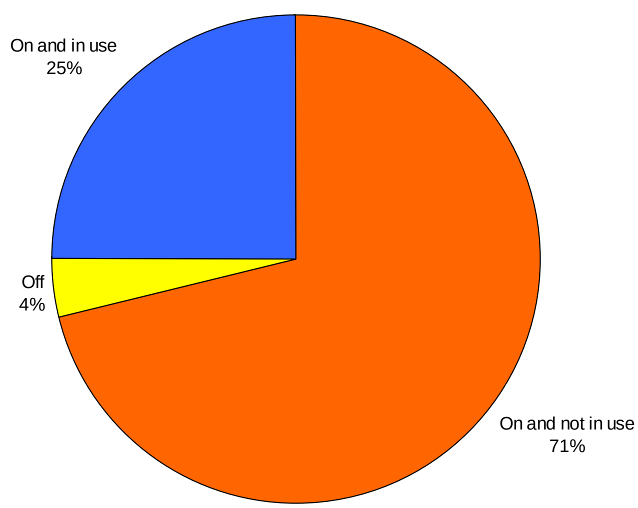


**Figure 5: Proportion of total time that computers were on and in use, on and not in use, and turned off for a 14 day span including weekdays and weekends in rooms 2018, 2019, 2020 in the FASS**

Tables 1 and 2 indicate values for the number of idle computers for each hour in a time period, the quantity energy consumed by those idle computers, the quantity of carbon dioxide, sulphur dioxide, and nitrogen dioxide emitted by coal power plants to generate electricity, and the cost of that electricity. These values were calculated for the hours during which the FASS computer labs were open. The last set of values was calculated for an eight month period of time to represent the normal academic year.

Table 1: Estimated minimum number of idle computers, energy consumed, pollutants emitted, and cost over an eight month period for time when FASS computer labs are open to students

| Time Period | (Number of computers idle) x (hours) | kWh | Coal (metric tons) | $CO_2$ (metric tons) | $SO_2$ (kg) | $NO_2$ (kg) | Cost ($) |
|---|---|---|---|---|---|---|---|
| One hour | 57.9 | 6.95 | 0.003 | 0.01 | 0.02 | 0.02 | 0.45 |
| One day | 739.6 | 88.76 | 0.03 | 0.08 | 0.23 | 0.23 | 5.77 |
| One week | 5177.5 | 621.30 | 0.23 | 0.59 | 1.60 | 1.63 | 40.38 |
| One month | 22189.1 | 2662.69 | 0.89 | 2.54 | 6.87 | 7.00 | 173.08 |
| Eight months | 178992.1 | 21479.06 | 7.92 | 20.49 | 49.91 | 50.90 | 1396.14 |

Table 2: Estimated maximum number of idle computers, energy consumed, pollutants emitted, and cost over an eight month period for time when FASS computer labs are open to students

| Time Period | (Number of computers idle) x (hours) | kWh | Coal (metric tons) | $CO_2$ (metric tons) | $SO_2$ (kg) | $NO_2$ (kg) | Cost ($) |
|---|---|---|---|---|---|---|---|
| One hour | 57.9 | 17.38 | 0.006 | 0.02 | 0.04 | 0.05 | 1.13 |
| One day | 739.6 | 221.89 | 0.08 | 0.21 | 0.57 | 0.58 | 14.42 |
| One week | 5177.5 | 1553.24 | 0.57 | 1.48 | 4.00 | 4.08 | 100.96 |
| One month | 22189.1 | 6656.73 | 2.23 | 6.35 | 17.16 | 17.51 | 432.69 |
| Eight months | 178992.1 | 53697.64 | 19.80 | 51.23 | 124.76 | 127.26 | 3490.35 |

Table 1 refers to minimum values based on an assumption of an idle computer consuming 120 watts of electricity (Tufts Climate Initiative, 2004). Table 2 refers to maximum values based on an assumption of an idle computer consuming 300 watts of electricity (Energy Management, 2004). All of these values are based off of a cost of electricity of 6.5 cents per kWh (Appendix 1), a thermal energy of coal of 6780 kWh per metric ton of coal, a 40% efficiency of a coal power plant, 2.85 metric tons of CO2, 7.7 kg of SO2, and 7.9 kg of NO2 being produced per metric ton of coal burned (HowStuffWorks, n.d.).

These calculations indicate that a minimum of 20.49 metric tons (Table 1) and a maximum of 51.23 metric tons (Table 2) of $CO_2$, a minimum of 49.91 kg (Table 1) and a maximum of 124.76 kg (Table 2) of $SO_2$, and a minimum of 50.90 kg (Table 1) and a maximum of 127.26 kg (Table 2) of $NO_2$ may be emitted to run these idle computers for eight months during times that the lab was open. Further, the university may be spending between $1396.14 (Table 1) and $3490.35 (Table 2) to run these idle computers during these time periods.

Figure 6 shows the frequency of age of the participants to the survey.

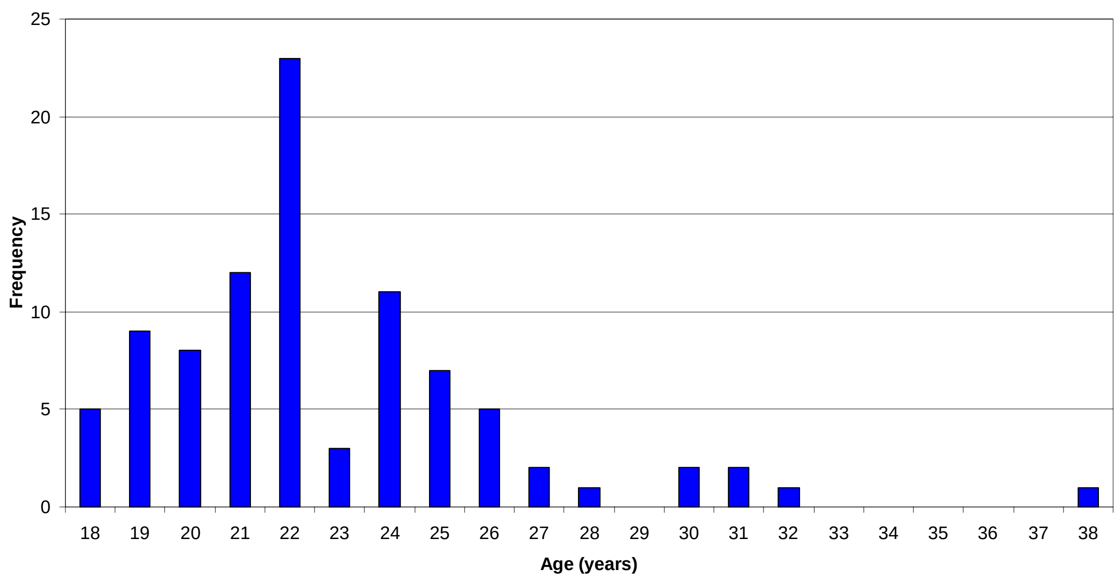


**Figure 6: Age of survey participants**

The mean age of respondent was 23.97 years old with a standard deviation of 4.13 years of age, and the modal age was 22 years old. The ages of respondents ranged from 18 to 38 years of age. As Figure 7 demonstrates, the participants to the survey belonged to a total of six faculties. The majority of respondents, 54%, were from the Faculty of Arts.

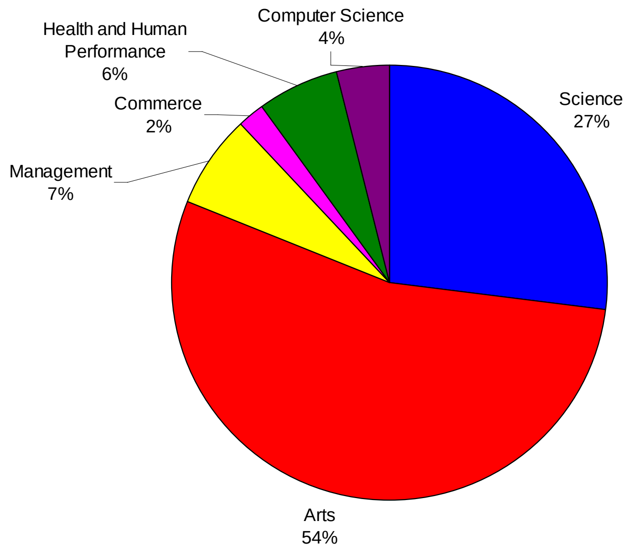


**Figure 7: Faculties represented by survey participants**

As seen in Figure 8, users reported that they were most likely to use the computer lab between the hours of 11:01 AM and 2:00 PM. The second most frequent time of use was between 2:01 PM and 5:00 PM.

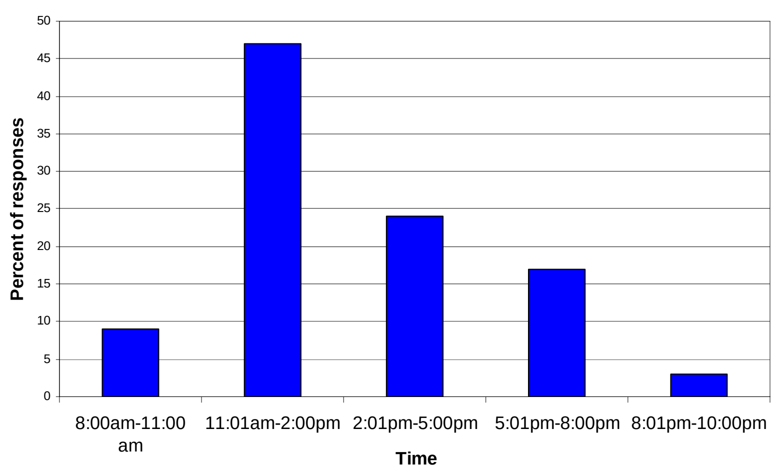


**Figure 8: Time of day of most frequent use of FASS computer labs as reported by students**

Figure 9 demonstrates that, of the participants polled, 79% reported that they use the computer lab more than eleven hours per week.

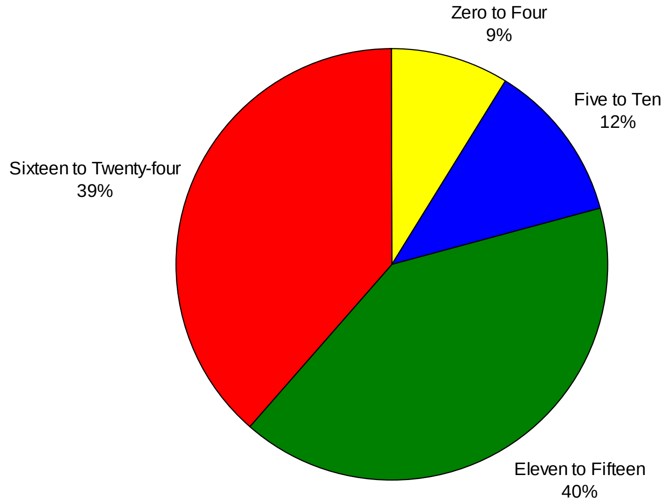


**Figure 9: Number of hours that respondents thought computers were left on during a normal day in the FASS computer labs**

Figure 10 shows that the majority of students, 53%, felt that the computers should not be turned off after each use, 23% thought that the computer should be turned off after each use, and 24% were unsure.

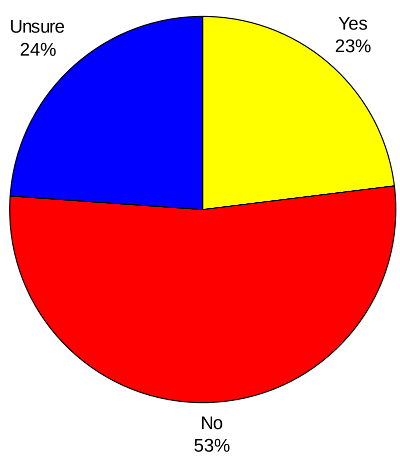


**Figure 10: Participants response to whether computers should be turned off after each use**

Of those that thought the computers should be turned off after each use, Figure 11 shows that the majority felt that the user should be responsible for turning off the computers.

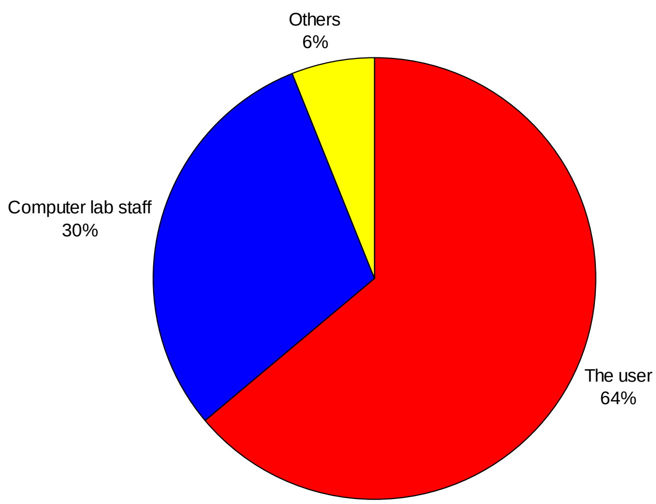


**Figure 11: Response to question asking who should be responsible for turning off computers if a participant thought that computers should be turned off**

82% of respondents reported that they would be willing to turn off their computer after each use, as seen in Figure 12. 13% reported that they would be unwilling to do so, and 5% were unsure.

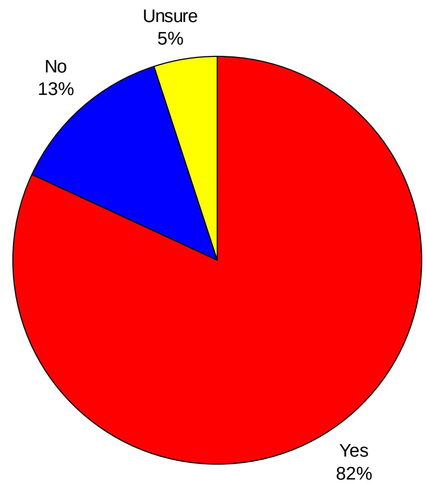


**Figure 12: Response to whether participants would be willing to turn off their computer after each use**

Figure 13 shows that 78% of participants would not use the computer labs less frequently if they were required to turn their computer on and off with each use.

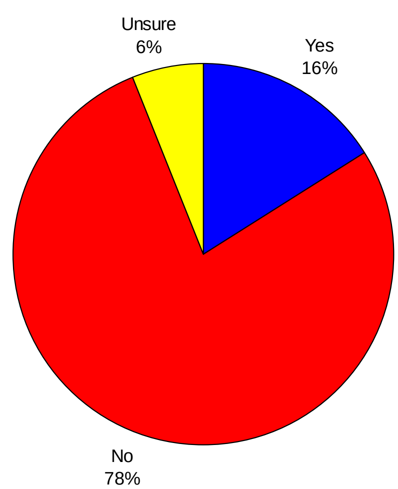


**Figure 13: Response to whether participants would be less likely to use the computer lab if they were responsible for turning their computer on and off for each use**

16% of participants would be less likely to use the computer lab if they were required to turn their computer on and off with each use, and 6% were unsure. Of those participants whose computer use would not be affected by having to turn computers on and off with each use, 92% reported that this was because it did not take that much more time to turn off or on than to log off or on, and 8% said their use would not be affected because they felt it was a moral responsibility.

Figure 14 demonstrates that the majority of respondents, 88%, report not turning their computer off after each use. 9% reported sometimes turning off their computer, and only 3% reported always turning off their computer.

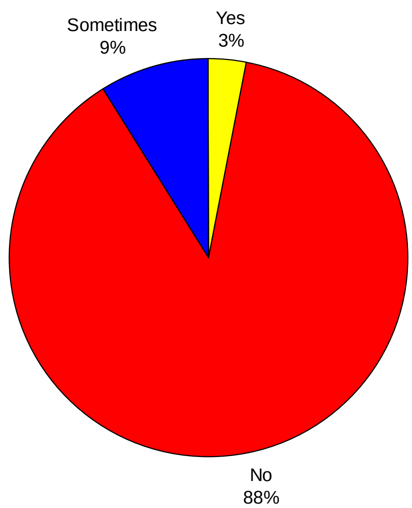


**Figure 14: Response to whether participants turn their computer off after each use**

When asked whether participants thought that it was better for a computer to be turned off than to be left on, if it was going to be unused for thirty minutes, 44% thought it would be better for the computer to turn it off, 28% thought it would be damaging to the computer, and 28% were unsure (Figure 15).

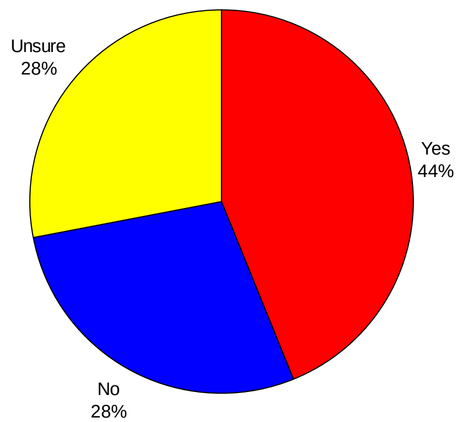


**Figure 15: Response to whether participants thought that it was better for computers to be turned off than left on if unused for 30 minutes**

As seen in Figure 16, when asked whether they thought that it is better for energy consumption if a computer is turned off rather than left on if it will be unused for thirty minutes, 55% thought it would use less energy, 14% though it would use more energy, and 31% were unsure.

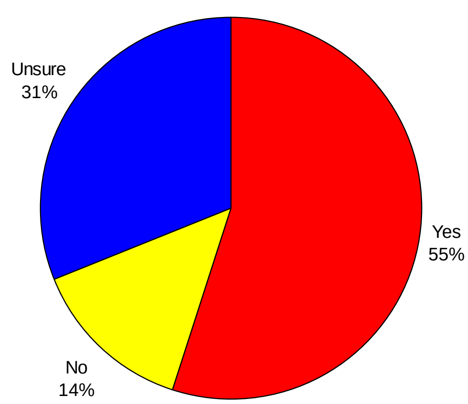


**Figure 16: Response to whether participants thought that it was more energy efficient to turn a computer off than to leave it on if unused for 30 minutes**

Figure 17 shows that 78% of users thought that computers left idle during the day were harmful to the environment, 16% were unsure, and 6% thought these idle computers would result in a positive effect for the environment.

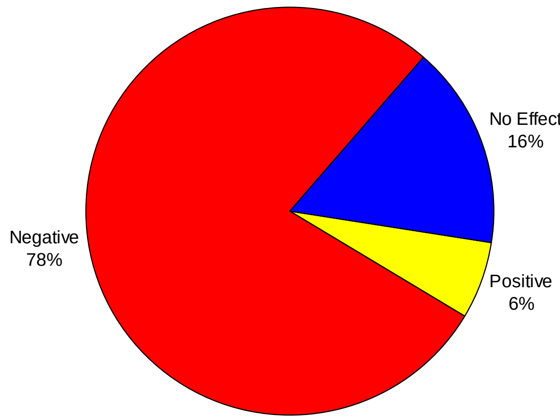


**Figure 17: Response to the overall effect that participants thought that leaving a computer on during the day had on the environment**

Of those respondents who thought that idle computers were harmful to the environment, 92% factors related to energy consumption, 5% mentioned radiation concerns, and 3% mentioned a decreased lifespan of the computers (Figure 18).

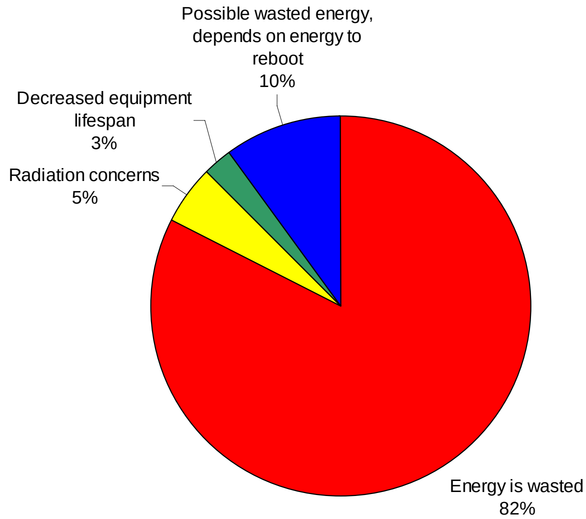


**Figure 18: Participants' explanation for why they believed that leaving computers on during the day may have a negative effect on the environment**

# Discussion

The main purpose of this study was to determine the extent of time which computers within the student computer labs of the FASS were on and not being used. This can be related to energy waste on the Dalhousie Studley campus and the excess consumption of fossil fuels leading to increased emissions of greenhouse gases such as carbon dioxide. The goal of the study was to bring this energy waste to the attention of the Dalhousie community and suggest some possible alternatives to leaving the computers on while they are not being used.

The results of our data collection have shown that the computers in the labs, rooms 2018, 2019 and 2020, were consistently on and not in use. On average, the labs were busiest during the week between the hours of eleven and four (Figure 2). With these hours being the only time of day during the week when there were more computers on and being used, than those which were on and not being used (Figure 2). On the weekend, there was no time period observed in which there were more computers on and being used than on and not being used (Figure 4). On average, during the week 25% of computers were being used (Figure 5). The majority of remaining computers were left on and that energy is being wasted. This could potentially be saved by turning computers off when they are not being used.

The hours which were considered the busiest within the computer labs were from 11am to 4 pm during the week. This makes sense as this is the time when most students are present on campus and attending classes. This indicates that at some points of the day are using more computers than the average, but at non peak hours a larger portion of computers are being left on while not being used. If at the peak hours it was observed the computers were not all being used, it seems that there are more computers being left on than is needed by the computer users.

On the weekend it was found that generally more computers were turned off than during the week, less than ten during the week, while on weekends there were at times fifteen computers turned off (Appendix 7). The number of computers turned off differed in each room. Although more computers were off on the weekend, compared to the number which were on and not being used, it was still a relatively small proportion of the computers and energy was still ultimately being wasted.

Each room within the study had a slightly different pattern of use. Room 2019 was the largest room, which contains 46 computers. Since it had the greatest number of computers it was also the room with the most activity. Computers within this room were rarely turned off and at the same time the room was also rarely more the 75% full (Figures 1b and 3b, Appendix 7). This lab had an average of 59% of computers being used at all times during the week. On the weekend this room had an average of 33% of its computers being used. This reiterates the fact that there are more computers turned on than are being used both during the week and on the weekend.

Room 2018, which was the second largest with 21 computers, was the most consistently close to full, with an average of 62% of its computers being used during the week (Figure 1a). Computers were very rarely turned off in this room, similar to room 2019. On average during the weekend there were only 24% of computers being used (Figure 3a).

Room 2020 had the largest amount of computers turned off on the weekend with as many as thirteen out of fifteen computers off (Figure 3c). This room was also the least used out of all the rooms observed. This may be due to the fact that this room was often used for classes and during these times students were not allowed to use the computers. On average only 40% of computers were used in this room during the week and 13% during the weekend (Figure 3c).

All computer labs are used for classes and tutorials at different times during the day. Room 2019 is still available for use by students during this time while rooms 2018 and 2020 are limited to students participating in the classes. This affects the use by students, for when the door to the room was shut often students assumed this indicated that a class was being conducted. At times when no classes were in session the room was empty and computer were on. Also, in room 2020 when classes were being conducted, sometimes the computers were not being used at all while all computers remained on.

Although each room is used differently and by varying amounts of students, the general trend shows that especially during the weekends, a large portion of computers are left on when they are not being used. Within the computer labs in the FASS, this is an important problem which should be addressed. This shows that Dalhousie is consuming more energy than is needed to run the computer labs within the FASS. The extra energy use, due to computers being left on, is resulting in increased carbon dioxide being emitted to the atmosphere through the burning of fossil fuels and therefore contributing to the global problem of climate change (Union of Concerned Scientists, 2001).

Dalhousie University currently obtains its energy through Nova Scotia Power (Facilities Management, personal interview) which produces 90% of its energy through the burning of coal (Nova Scotia Power, 2005). The burning of coal has been shown to produce carbon dioxide and other greenhouse gases which contribute to global warming (Union of Concerned Scientists, 2001). It has also been shown to produce sulphur and nitrogen oxides which are a leading cause of acid rain (Union of Concerned Scientists, 2001). By obtaining its energy in this way, reducing the amount of energy being used on campus would not only save Dalhousie money but would also result in a lowering of carbon dioxide and other deleterious by-products from entering the atmosphere.

Although this study focused on a relatively small portion of Dalhousie's total computers, a number of important values were calculated. By shutting off these 82 computers within the FASS when they are not being used, during an eight month academic term, the university could save between approximately $1400 and $3500 (Figure 1 & 2). For the small amount of computers which this applies to, these potential savings could be substantial. Also, there are approximately 800 student computers on the Dalhousie campus (and similar studies can be done to examine their use). This implies that there is potential for Dalhousie to save a large amount of money simply by turning off idle computers, which are not being used (O'Hara, 2005: Appendix 1). Also, by shutting off these 82 computers within the FASS when they are not being used, between 20.49 and 51.23 metric tons of carbon dioxide can be prevented from entering the atmosphere and contributing to environmental problems (Figure 1 & 2). Shutting off computers seems to be a simple solution to a problem which is contributing to excess spending on the Dalhousie campus and also resulting in harmful impacts on the environment.

For these changes to be implemented it is important to find out the opinion of the students of Dalhousie University and how they would feel about potentially shutting computers off after they are used in the FASS. In order for energy saving programs to be effective it has been shown that student support is critical (Tufts Climate Initiative 2005).

The survey results that were gathered throughout this study should be of particular interest to Dalhousie University because of the declarations it is already a part of. Dalhousie has agreed to the Talloires declaration, which is a commitment to environmental responsibility and education (Talloires,1990). Within this declaration the university agrees to operate sustainable and physical operations, as well as to promote sustainable research (Talloires,1990). The university has also signed on to the Halifax Declaration, which is a movement towards environmental sustainability on campus (Talloires,1990). The survey responses that were given in this study show areas (both in terms of education and conservation) where the university needs to improve in order to be in compliance with those declarations.

User perception was researched in order to find out how students felt about computer use in the FASS. For the study to gain catalytic validity, it was important to determine if students would welcome change. First, the times at which students visited the labs had to be determined. Students responded in the surveys that they frequent the computer labs most during the lunch hours, from 11:00 AM to 2:00 PM (Figure 8) which was also found in the analysis of the observed data (Figure 2). This makes sense as these are the building's busiest times throughout the day. Next, the study attempted to determine users' thoughts about turning computers off. When asked if students felt that the computers should be left on throughout the day, the majority responded that they believe that they should (Figure 10). The main reasons given for this response were time and convenience. Though most did not think it would be a problem, some students expressed that they use the computer labs during class change, and the extra time needed to turn on a computer would be too long to make this an option. Finally, to find out if change would be possible users were asked if they could change their habits. When asked if it was the user's responsibility to turn his/her computer off after each use 82% of students said that they would willingly comply (Figure 12). To the same effect, 78% of students would not frequent the lab less if this were the case (Figure 13). These results imply that alternatives to leaving computers on and idle all day can be implemented without causing too much disruption to student life. These survey questions have shown that it is possible to make small changes to conserve energy and save money on Dalhousie campus.

A portion of the questions asked in the survey were designed to test students' knowledge of the computers they use, and their overall effects. It was found that students were unsure about what does and does not harm computers. 44% of the students surveyed believed that it is harmful to the computer to turn it off after only being idle for

30 minutes.  28% believed that it is not harmful, and the other 28% were not sure (Figure 15).  A common theme throughout the comments given with respect to this question was that despite the participant's answer he/she did not really know, or necessarily understand the effects of turning on/off a computer.  This suggests that general education of computer users is necessary in order for them to understand any impact that their actions have.

One of the most important pieces of knowledge gained from this survey pertained to the environment.  When asked if the effects of an idle computer on the environment were positive, negative, or none, the majority of students responded negative (Figure 17).  The main reason given for this negative effect was the unnecessary use of power.  Some students linked this use of power to the burning of fossil fuels and global warming, but for the most part this link did not come up.  Again, a large portion of those students that responded that computers have a negative environmental impact were unsure of why.  This demonstrates the lack of connection that students have between their actions and their environmental effect.

## Recommendations for Dalhousie University

In order for Dalhousie to implement this energy savings changes need to occur within the structure of how the computers and labs are managed in the FASS.  The most efficient option would be for all computers in the FASS to be turned off when they are not being used. "Logging off" should not be an option and the user would be required to shut the computer off to log themselves off the system.  Since most students stated that this would not affect their use of the lab or that they would be willing to do this, it seems like a positive and effective plan.

Alternatively if Dalhousie is not willing to implement turning off computers at all times, potentially the same program could be undertaken with computers being turned off only on the weekends when there are fewer users of the lab.

Another solution to the problem could involve the closing of the two smaller computer labs during non-peak hours during the week and also on the weekend. By closing the computer labs, it is meant that the computer labs will be locked with all computers within the rooms being turned off. If all labs were open from 11AM to 4 PM during the week and shut off the rest of the time, there should be sufficient number of computers to satisfy the use.

## Recommendations for further studies

Based on the findings of this study, it is recommended that a similar study be done during the summer academic term and during exam periods when the computer use patterns are likely to be different than those determined in this study. It is also important to get more accurate information from Nova Scotia Power on the type of coal and the methods used in the combustion process to determine the exact environmental impacts caused through the consumption of excess energy. More accurate numbers also need to be found to calculate the exact amount of energy each computer within the FASS requires so that instead of giving minimum and maximum numbers accurate values can be calculated. Further research should also be done on technological advances in computers and also in programs which can help prevent energy from being wasted in idle computers.

## Conclusions

The study on FASS computer labs should act as a stepping stone for other research projects in the future. It has been proven that there is the potential for energy savings within the university, and it is hoped that this study will provoke further investigation into the computer labs not only in the FASS, but across campus. Because this study is the first of its kind conducted on the FASS building, it should have noteworthy impacts for the university. It is possible that a change in how the computer labs are run has never been considered in the past. In light of this study, however, it will be proven that the university should research to find out where energy is being used unnecessarily, and make appropriate changes. To add validity to the study conducted on the FASS, it was found that several similar studies have taken place in many different parts of the world, and all have shown only positive results in terms of savings (Adcock, 1995 and Tufts Climate Initiative, 2005)

After having performed this study, there are many implications from the results. It has been shown that the university can save both energy and money, as well as lower its environmental impact by reducing the number of computers that are left idle during the day. This study should be used as a starting point for other larger scale studies within Dalhousie University. It is not possible to extrapolate the data found in this study to the scale of the entire university as there are many variables that change from building to building. For example, different types of computers use different amounts of energy. In the same manner, the same solution may not work for each computer lab for networking or technological reasons. However, this study has shown that there is room for improvement within the institution, and that there is the potential for savings. In order for Dalhousie University to move ahead in terms of environmental education and sustainability, excess energy use should be considered. Further research should be conducted to calculate more accurate and large scale values for savings both in terms of the environment, and financially.

It is hoped that this study will also act as a motivational tool for other institutions that have a large number of computers.  This study has shown that there is potential for savings by making small changes, which should encourage businesses and other schools to investigate their own energy use.  As more and more institutions begin to re-evaluate how their energy and money is spent, it is hoped that they will become continuously more efficient.  This project has the possibility to cause positive change.  Not only can organizations save money and energy, but they can also reduce their greenhouse gas emissions, thus lowering their environmental impact.

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# Appendices

## Appendix 1: Personal Interviews

### E-mail Interview with Neil Landry, Zone 2 Coordinator of Maintenance

The following questions were asked in the interview:

1. How much energy does the Faculty of Arts and Social Sciences (FASS) Building use in total per year?

2. How many student use computers (see definition of student use computer) are there in the FASS building?

3. Do the computers in the student labs get turned off at the end of the day?

4. Who is responsible for turning off the computers before the building is closed?

5. Please provide us with any further information that you have regarding the topic of study.

6. The response received provided us with the contact information for Marc Serroul.

### Summary of Conversation between Peter Howett and Kathryn Smith (Feb. 2, 2005)

1. Questions asked:

2. Does Dalhousie have a program in place where all computers are turned off overnight?

3. How many computers are on Dalhousie’s campus?

4. Have previous studies been done?

5. Do you believe energy waste from computers is a problem?

6. How much does Dalhousie pay per Kilowatt hour for electricity?

7. Who would be in charge of shutting off the computers?

We were put in touch with Peter Howett through Mike Murphy, facilities management manager at Dalhousie University. According to Mr. Howett, Dalhousie University had previously conducted a similar study to the one in which we are beginning which found that the university would save money by shutting computers off when not in use. He felt this would be a useful project because although facilities management asks all departments to shut off computers he was unsure as to whether this is actually being done. He can not be sure of the number of computers on campus, but suggested making contact with Phil O'Hara of Computing Services. He also suggested contacting PCPC, which deals with all Dalhousie computer purchases and may have records of the number of computers bought by Dalhousie.

Mr. Howett was able to suggest methods to calculate the amount of energy used by the computers by calculating the number of watts used by the computer per hour and multiplying by the number of hours the computer is idle, then dividing by 1000 to provide a figure in kilowatt hours. By multiplying this figure by 6.5 cents, which is approximately what Dalhousie pays per kilowatt hour, the amount of money which would be saved by shutting off a computer while it is not being used would be calculated.

## Summary of Conversation between Phil O'Hara and Kathryn Smith (Feb. 2, 2005)

**Questions asked:**

1. How many computers are located on Dalhousie's campus?

2. Are these computer's shut of at night?

3. Who is in charge if doing this?

Mr. O'Hara estimated the number of computers located in student computer labs across Dalhousie's campus as approximately 800. He was unsure as to what computers were left on while not in use, but based on personal observation felt that it was occurring. He also recommended a similar study done at the University of New Brunswick in which the university calculated an estimated $50 000 annually in savings by altering their computer energy use. Greg Sprague was the contact given at the University of New Brunswick who may be able to help in obtaining a copy of the study.

## Summary of Conversation Between Marc Serroul and Christie Thomson (Feb. 10 2005)

**Questions Asked:**

1. Are the computers in the FASS turned off overnight?

2. Who is responsible for turning off the computers in the FASS?

3. Are the computers in the FASS equipped with Energy Star components?

4. Are the Energy Star components activated on the computers in the FASS?

5. How many computers are in the labs in the FASS?

Mr. Serroul informed me that the computers in the labs are always left on overnight, and that the computer staff is told to make sure that they are left on before the lab closes. The reason for this is to allow for anti-virus updates and network maintenance. He told me that the computers have a "frozen" feature. This means that when a user is using the machine he/she is able to save whatever he/she wants on the desktop and overnight, they thaw out to their original settings to be ready for the next day. I asked if it was possible for the computers to get the updates while they were on and he said no because the computers have to be idle. Mr. Serroul said that this process starts around 1am and takes between 4-5 hours and therefore the computers need to be left on overnight.

Next, I asked him about Energy Star. He said all of the machines have the features, but they are not enabled because they conflict with some of the other processes the computer must be doing. For example, the computers are supposed to reset themselves after 20min of not being used. He said that that would wipe out all of the Energy Star components and it would be useless.

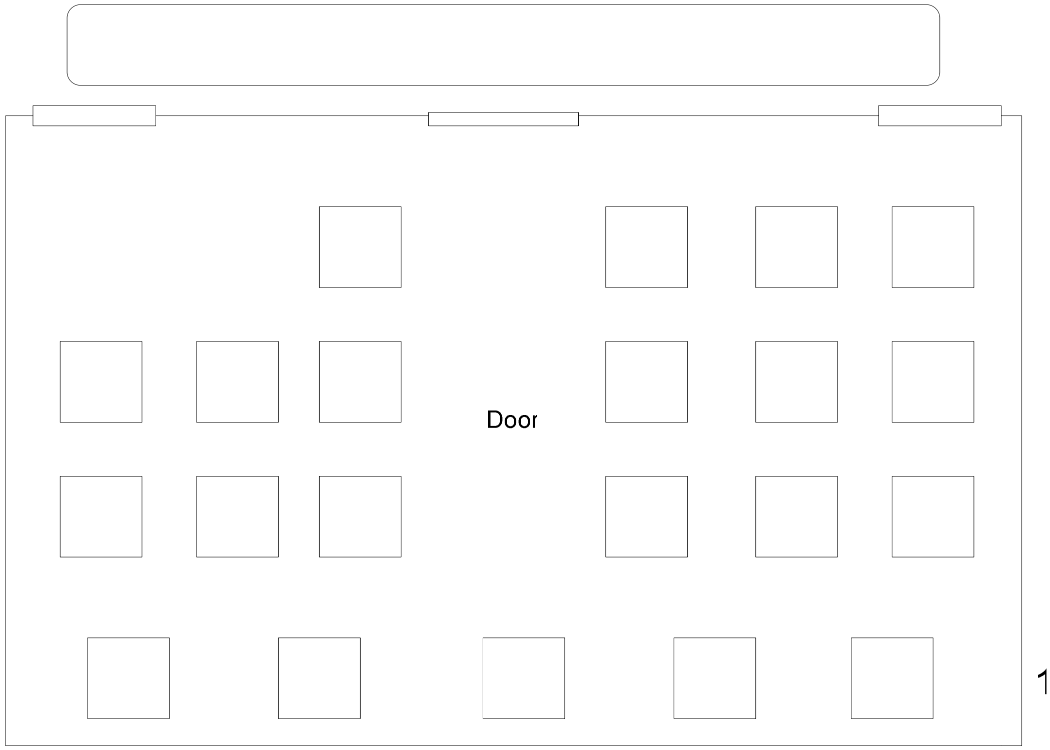
He also told me that he is only responsible for certain buildings. He isn't in charge of the Killam Library, but he said that they must be on the same system.

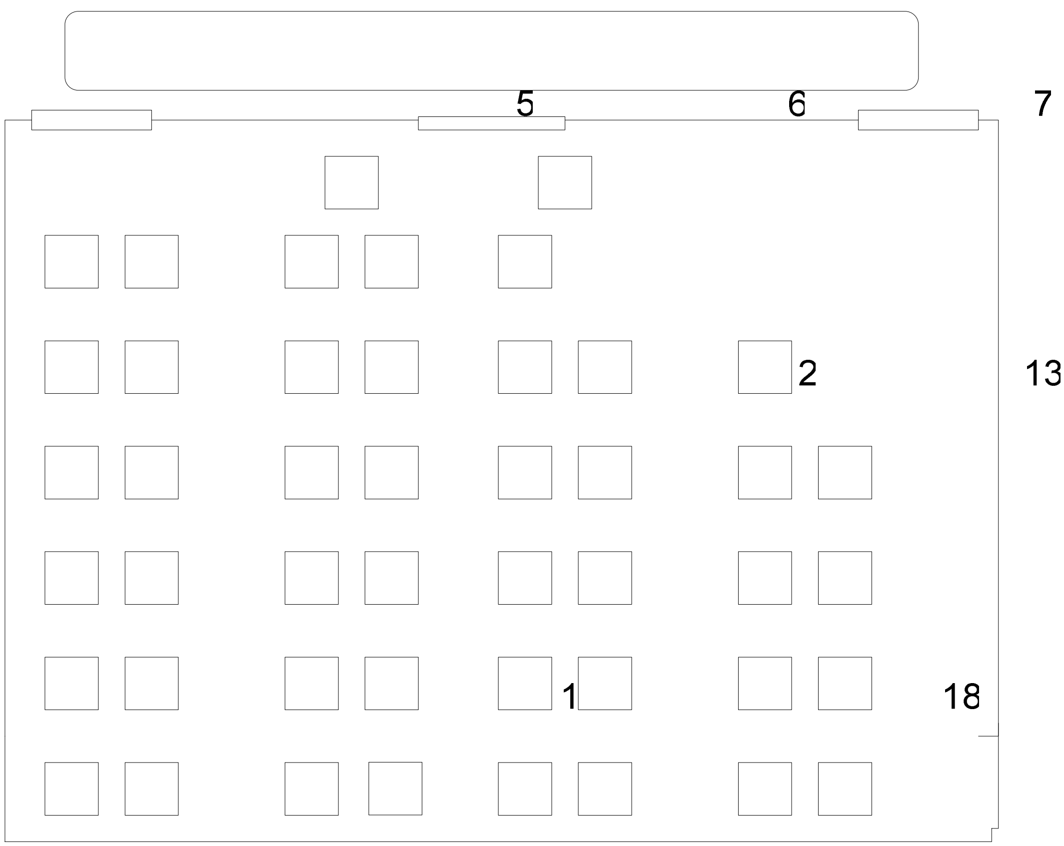
He estimated that there are around 130 computers in the labs in the FASS and that they use "an insignificant amount of energy"

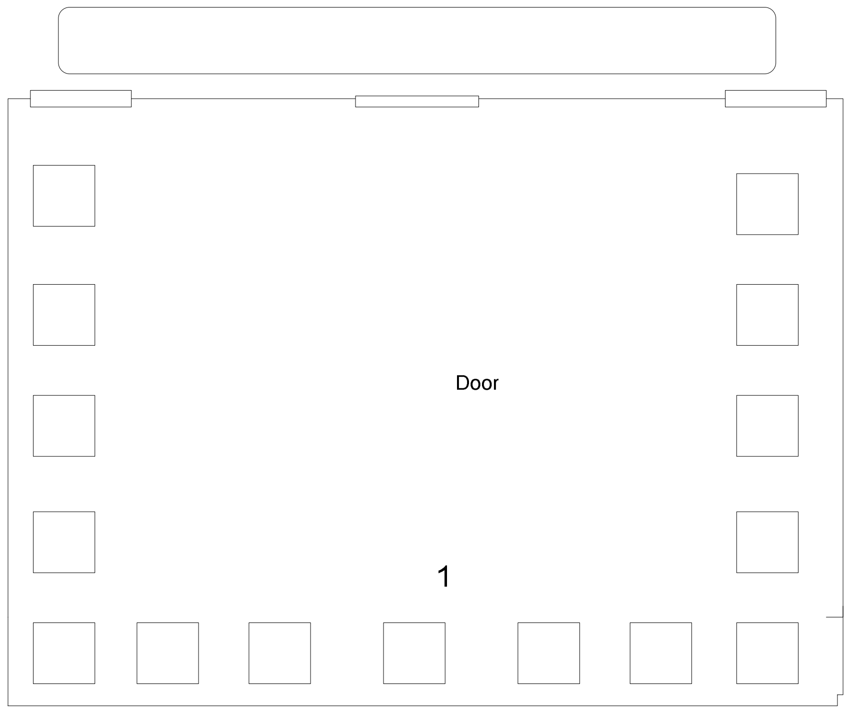
## Appendix 2: Times at which the labs were observed

| | Monday | | Tuesday | | Wednesday | | Thursday | | Friday | | Saturday | | Sunday | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 48 | Julie | 1 | Christie | 36 | Julie | 4 | Kat | 0 | Christie | 2 | Christie | 58 | Kat |
| 9 | 13 | Julie | 11 | Ainslie | 42 | Dianne | 25 | Julie | 14 | Dianne | 31 | Kat | 9 | Kat |
| 10 | 54 | Ainslie | 27 | Christie | 40 | Ainslie | 26 | Christie | 21 | Christie | 19 | Kat | 2 | Kat |
| 11 | 29 | Dianne | 37 | Kat | 20 | Kat | 58 | Dianne | 28 | Sean | 14 | Dianne | 57 | Christie |
| 12 | 33 | Sean | 44 | Ainslie | 8 | Ainslie | 54 | Sean | 4 | Christie | 6 | Dianne | 59 | Christie |
| 1 | 37 | Christie | 2 | Julie | 28 | Christie | 50 | Julie | 18 | Kat | 59 | Christie | 4 | Christie |
| 2 | 28 | Kat | 9 | Christie | 37 | Kat | 18 | Julie | 32 | Dianne | 6 | Christie | 45 | Dianne |
| 3 | 22 | Kat | 15 | Sean | 9 | Julie | 36 | Kat | 38 | Dianne | 19 | Sean | 26 | Dianne |
| 4 | 7 | Sean | 1 | Dianne | 43 | Sean | 30 | Christie | 48 | Kat | 14 | Sean | 53 | Sean |
| 5 | 22 | Julie | 49 | Dianne | 3 | Ainslie | 5 | Sean | 15 | Kat | 6 | Sean | 24 | Sean |
| 6 | 36 | Ainslie | 50 | Julie | 45 | Kat | 19 | Kat | 48 | Sean | | | | |
| 7 | 53 | Ainslie | 25 | Christie | 13 | Christie | 50 | Julie | 9 | Sean | | | | |
| 8 | 14 | Julie | 43 | Julie | 24 | Christie | 14 | Julie | 26 | Christie | | | | |
| 9 | 27 | Christie | 28 | Ainslie | 54 | Ainslie | 56 | Julie | 54 | Christie | | | | |

## Appendix 3: Sample data sheets


Door
1


5
6
7
2
13
1
18




2

## Appendix 4: Survey and consent form

### Survey of Students Using the Faculty of Arts and Social Sciences

3

### Computer Labs

Are you: Male Female
Age: ______
Faculty: ____________________ 4

1. In a typical day, what time of day do you most frequently use the Faculty of Arts and Social Sciences computer labs?

   a. 8:00 am – 11:00am 5 6 7 8
   b. 11:01am – 2:00pm
   c. 2:01 pm – 5:00pm
   d. 5:01 pm – 8:00pm
   e. 8:01pm – 10:00pm

2. During a normal weekday how many hours do you think the computers are left on in the Faculty of Arts and Social Sciences computer labs?

a. 0 – 4
b. 5 – 10
c. 11 – 15
d. 16 – 24

3. Do you think the computers should be turned off after each use?

a. yes
b. no
c. unsure

If yes proceed to question 3a.

3a. Who do you think should be responsible for turning off the computers?

a. The users (students)
b. Computer lab staff
c. Other; please specify: _____________

4. Would you be willing to turn off your computer in the lab after using it?

a. yes
b. no
c. unsure

5. Would you be less likely to use the computer lab if you were responsible for turning the computer on and off before and after use?

a. yes
b. no
c. unsure

Please explain:

6. In the computer lab, do you turn off your computer after use?

a. yes
b. no
c. sometimes

7. If a computer is not being used over a 30 minute period, is it better for the computer to turn it off than to leave it on?

a. yes
b. no
c. unsure

8. If a computer is not being used over a 30 minute period, is it more energy efficient to turn the computer off than to leave it on?

a. yes
b. no
c. unsure

9. What kind of overall effect do you think leaving a computer on during the day has on the environment?

a. positive
b. negative
c. no effect

Please explain:

## Consent Form

This survey will be used as part of a study to determine whether or not energy is wasted from leaving computers on while not being used throughout the day. The information gathered from this survey will be used to determine whether the wasting of energy is perceived as a problem in the university, and if so, how it relates to the environment. No personal information given in this survey will be released.

The results of our study will be obtainable from Tarah Wright (tarah.wright@dal.ca), or via the Environmental Programmes website, http://environmental.science.dal.ca/index.html, as of April 8th, 2005. Email addresses are provided below should you wish to contact any member of the group carrying out the study.

## Appendix 5: Calculations

The mean number of idle computers in all computer labs per hour for a week was calculated from data obtained. The mean number of idle computers for weekdays was given a weighting of 5/7 and the mean number of idle computers for the weekends was given a weighting of 2/7 to represent the proportion of weekdays and weekend days in a week. Based on the number of hours in a day, week, month, and eight month academic term the mean number of idle computers turned on for each hour was calculated.

**Mass (metric tons) of CO2 released by idle computers per time period =** (Computers X hours idle per time period) X (kWh/computer) X (metric tons of coal needed per kWh produced by burning coal) X (metric tons of $CO_2$ released per ton of coal burned)

**Mass (kg) of $SO_2$ released by idle computers per time period** = (Computers X hours idle per time period) X (kWh/computer) X (metric tons of coal needed per kWh produced by burning coal) X (kg of $SO_2$ released per ton of coal burned)

**Mass (kg) of $NO_2$ released by idle computers per time period** = (Computers X hours idle per time period) X (kWh/computer) X (metric tons of coal needed per kWh produced by burning coal) X (kg of $NO_2$ released per ton of coal burned)

**Cost of energy consumed by idle computers per time period ($)** = (Computers X hours idle per time period) X (kWh/computer) X (cost per kWh of energy produced ($))

## Appendix 6: Ethics Form

Please refer to hard copy of report.

## Appendix 7: An example of the Excel spreadsheet for one day of data collection in one room

For the complete data spreadsheet please refer to the Environmental Programmes website: http://environmental.science.dal.ca/index.html

### Room 2018

| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monday, Feb. 28 | | On/Use | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 |
| | 8:48 | On/Not | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 17 |
| | | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | On/Use | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 4 |
| | 9:13 | On/Not | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 17 |
| | | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | On/Use | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 14 |
| | 10:54 | On/Not | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 7 |
| | | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | On/Use | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 10 |
| | 11:29 | On/Not | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 9 |
| | | Off | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| | | On/Use | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 14 |
| | 12:33 | On/Not | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| | | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | | On/Use | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 14 |
| | 1:37 | On/Not | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 8 |
| | | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | On/Use | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 14 |
| | 2:28 | On/Not | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 6 |
| | | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | | On/Use | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 10 |
| | 3:22 | On/Not | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 10 |
| | | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4:07 | On/Use | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| | On/Not | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 12 |
| | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5:22 | On/Use | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 8 |
| | On/Not | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 13 |
| | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6:36 | On/Use | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 4 |
| | On/Not | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 17 |
| | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7:53 | On/Use | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | On/Not | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 19 |
| | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8:14 | On/Use | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| | On/Not | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 19 |
| | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9:27 | On/Use | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| | On/Not | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 19 |
| | Off | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |