Patterns of dorm energy use and potential opportunities for dorm energy conservation at Colby College

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Colby College

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Patterns of Dorm Energy Use and Potential Opportunities for Dorm Energy Conservation at Colby College

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A thesis submitted to the faculty of the Environmental Studies Program in partial fulfillment of the graduation requirements for the Degree of Bachelor of Arts with honors in Environmental Studies

F. Russell Cole, Principal Mentor

Thomas H. Tietenberg, Reader
I. Introduction

The need to reduce energy use is more than an environmental matter; it is a pressing monetary issue. The rising oil prices that began last fall have sparked a rise in energy prices that is affecting everyone. Fossil fuel resources are finite in supply and detrimental to the earth’s atmosphere once used and carbon dioxide is released, contributing to global warming. Energy prices are increasingly high and do not appear to be headed on a downward trend any time in the future (Energy Information Administration 2006). The time to explore and adopt alternative energy solutions is now. Alternative energy solutions include use of renewable energy resources and establishing different patterns for using energy consuming appliances and machines. Knowing which choices make the most sense for this institution, Colby College, at this time requires a firm understanding how current energy use matches possible opportunities.

This thesis research began in the fall; around the same time President Adams predicted that the school would pay one million dollars more than budgeted this academic year on energy due to the rising energy prices (Adams, pers. comm.). Students, their families, and the college would bear this monetary burden. Solutions that lower energy costs would benefit many different parties. Dorms use a large amount of energy. Unlike many energy demands on campus that are relatively constant, dorm rooms are flexible in their energy use because students can change their energy use patterns. Many areas of energy waste characterize dorm room life at Colby. Numerous opportunities exist to address these problem areas such as reducing wasted heat and turning off appliances when not in use. Awareness education may play a role. Many students appear misinformed about sound energy practices. Despite dialogue between students and
staff/administration, this research indicates much remains to be discussed and changed. The gap between energy use knowledge and practice must be narrowed at Colby and by providing the basic analysis needed to understand the nature of the problem, this thesis is intended as one step in that process.

Three sources of information inform the analysis in this thesis: (1) ideas from energy saving efforts at other schools; (2) a detailed survey on energy consumption practices of Colby students; (3) a comparison of actual electricity consumption in paired dorms, one in each pair receiving energy saving treatments.

Outside of Colby College, the successful steps other colleges and universities have taken to lower energy use in dorm rooms are pertinent to this study because some successes can be applied to the Colby context. These success stories are also relevant because they demonstrate the strength of the campus sustainability movement among colleges and universities. Bowdoin College, Brown University, Harvard University, and many other schools have hired the equivalent of sustainable coordinators and set up an infrastructure between students and staff to work on numerous energy saving projects (Bowdoin College 2006A, Brown University 2006, Harvard Green Campus Initiative 2006A). Oberlin College is one of a few schools on a new path by making dorm electricity use data available online for all students to check (Oberlin College 2006A). Colleges are an opportune environment for sustainability and conservation initiatives because of the resources they possess (both financial and labor) and the impact the initiatives will have on the students (Oberlin College 2006A). Students are going to go out into different areas of many societies and, if they are aware of their energy use, these messages could reach many more people and places than could currently be foreseen.
Dorms are difficult places to conserve energy because students are disconnected with the amount or cost of energy they use. In a normal house or apartment living situation, the bill one receives every month with a record of energy used provides an economic incentive to conserve. In the dorms, students pay a room and board fee as a component of the comprehensive fee. They do not pay more or less based on the amount of energy and water they consume; consequently they have no direct negative repercussions for using too much energy or water. They also have no gauge of how much energy or water they are using. What this means for the greater college setting is that consumption of energy and water may be higher than necessary; this leads to environmental degradation, often at sites removed from campus, as well as more expense bills for the college.

It is necessary to investigate energy use patterns of students in order to discover the most effective avenues for energy conservation in dorms. It is important to quantify how much energy students use in their dorm rooms, which appliances they use most, and what types of energy use patterns are exhibited to establish trends. It is also important to understand why waste occurs. Misconceptions and unawareness about energy use are common problems, which can be corrected simply with better information (Harvard Green Campus Initiative 2006A). For example, many students believe monitor screen savers actually save energy, however they do not (Harvard Green Campus Initiative 2006A). The efforts and results reported in this thesis reflect not only the work of the author but also the context of the college. Environmental activism at Colby is a collaborative effort between students, faculty, and administration. Funding and communication are based on the institution's situation and capabilities. What works and has been most effective at Colby will not necessarily be a blue print for other larger
universities or necessarily similarly sized liberal arts colleges, but the trials and tribulations should enlighten other efforts. Information sharing and networking among colleges are crucial to strengthen the sustainability movement nationwide. One example for how Colby Environmental Studies Program and Environmental Advisory Group (EAG) share sustainability efforts is through the Green Colby webpage (www.colby.edu/green).

II. Campus Sustainability at Colby

The purpose of this thesis is to determine energy consumption patterns of students in dorm rooms at Colby College and explore potential areas to conserve electricity. This investigation used a multipronged approach that included an energy use survey, dorm experimentation and a compact fluorescent bulb exchange. A survey was created and administered to the whole student body to investigate use patterns, knowledge, and the practice of energy saving techniques on campus.

A dorm energy experiment was designed to explore implementation of multiple energy saving methods and evaluate energy using Colby’s electrical management system. With these data, tactics and future plans to save energy in Colby dorms were produced and the economic and environmental savings were estimated.

This thesis work joins a movement on campus that has been gaining momentum for many years. Colby has a strong Environmental Studies Program with a high level of faculty and student involvement. This is mirrored in the Environmental Advisory Group (EAG), a collaborative group of faculty, students and staff members that advise the president on environmental issues. The EAG is a model that could be implemented with
great success at other colleges and universities. Two key administrators are on the EAG, Vice President Douglas Terp and Director of the Physical Plant Department (PPD) Patricia Murphy. These two administrators meet frequently face-to-face with concerned faculty and students. They have the power to implement decisions resulting from EAG meetings. Advice from the committee does not get diluted before it reaches the President.

ES Program students and faculty have worked with the Physical Plant Department (PPD) and other administrators in many energy saving initiatives on campus as well as various other campus sustainability efforts over the last six years. Faculty members Professor Russ Cole, Professor Tom Tietenberg, and Professor David Firmage have helped pioneer campus greening efforts at Colby. Their involvement with Colby administration and faculty, the Environmental Studies Program, and the EAG creates a fluidity and common direction among all these environmental issues on campus.

This fall, the EAG decided to create sub-committees to allow smaller, interested groups to work on important campus sustainability issues. Beginning midway through the fall semester, the Energy Subcommittee identified target energy issues on campus and has worked to address those issues. The method the committee has used has primarily been campus energy education in a variety of forms. The members of the Energy Subcommittee have been dedicated and effective in their work. They are: Professors Russ Cole and Tom Tietenberg (committee chair); students Kerry Whittaker ('08), Jenny Venezia ('06), Liza Mitchell ('08), Sarah Hoskinson ('06), Jacquelline Rolleri ('06), Jamie O'Connell ('08) and Sarah Kelly ('06); and director of the PPD Patricia Murphy.
Energy use is an important issue at Colby College for many compelling reasons; one of the most obvious is the sheer amount of energy consumed in one year. In 2005, Colby purchased 13,169,374 kwh of electricity (DeBlois, pers. comm.). Last year Colby paid 8.1 cents per kilowatt hour for electricity, which means Colby spent $1,066,719 last year on electricity (Cheesman, pers. comm.). Colby is conscientious in its green energy purchasing. The current electrical package Colby purchased includes 244,681 kwh from wind power, with the remainder made up of 50% biomass and 50% hydropower (DeBlois, pers. comm.). Colby purchases its energy from Constellation New Energy. The energy is Maine Made 100% renewable and the wind power offset is Green-e certified (DeBlois, pers. comm.)

Energy reductions can occur in a multitude of forms. One way Colby has actively reduced energy use is by replacing older appliances and motors with more energy efficient models and technology in dorms and academic buildings. Front-loading energy efficient washing machines installed two years ago campus wide are estimated to save the college $10,000 a year in water and energy use. T-8 fluorescent bulbs have been replaced across campus with low mercury T-8 bulbs. These bulbs not only use 40% less power, they last 20% longer and contain 66% less mercury (Colby EAG 2004). PPD pays Phillips Electronics to take back the lights and reuse all materials and mercury (Dudley, pers. comm.). So far only 13 vending machines on campus have vending mizers (DeBlois, pers. comm.). Vending mizers act as motion sensors for the vending machines, causing them to turn on as one approaches the machine.

Prior to this thesis project, some classrooms, restrooms, and other spaces had motion sensors in place. Colby currently meters all but five of its residential dorms for electrical
usage (DeBlois, pers. comm.). PPD is beginning to incorporate energy saving designs in all new dorms being built or renovated. Corridor lights in newly renovated buildings are rewired so that every other light is on the same wire to lower light use during non peak hours (McCutcheon, pers. comm.). PPD then programs all the common area lights to be on during peak light use hours and half to be turned off during hours that students do not require as much light (McCutcheon, pers. comm.). Each of the hallways in newly renovated dorms is wired so that every other light is off during the hours before 4:00 pm and after 10:00 pm (McCutcheon, pers. comm.). This flexibility allows for more efficient lighting and energy conservation in dorm common spaces.

New dorms also receive many more heating zones, so that heating is more adaptable and fits the needs of more students than in older dorms. In each zone, one room has the thermostat for the other rooms in the same zone. Increasing the number of zones lowers the risk of windows being opened when rooms are too hot; this is a large waste of energy.

Other behavioral changes have been initiated on campus to lower energy waste. Professor Tom Tietenberg started the initiative where faculty members are formally notified via email when their class is the last class in a particular classroom or laboratory. Faculty members are requested to check that lights are turned off and windows closed before the room is vacated. Student workers are employed to turn off lights and shut windows in the laboratories and classrooms of the academic buildings. These types of changes demonstrate informed energy conservation. The changes reflect the energy use patterns of students and faculty and create a theoretical norm that all lights are off and windows are shut at night.
Larger internal changes to make Colby a greener campus have occurred. For example, a feed water economizer was installed at the central heating plant, reducing fuel oil consumption by an estimated 100,000 gallons per year by preheating the feed water (Colby EAG 2004). A co-generation turbine creates electricity from steam already generated for heating purposes. It produces an average of 1,700,000 kwh of electricity annually with savings in excess of $150,000 in reduced power purchases (Colby EAG 2004).

The Environmental Studies Program conducted research to calculate Colby's ecological footprint (Colby Environmental Studies Program 2005). An emissions audit outlining emissions since 1990 was created in 2004 and is being updated for 2005. Colby's long term emission reduction commitment was in response to the New England Governor's Regional Climate Change Action Plan in 2001 (Colby Environmental Studies Program 2005). By 2010, Colby has committed to reduce greenhouse gas emissions per square foot of building space by 9%.

My hope is that this thesis project will not be an end in and of itself, but rather a step in Colby's move toward being a sustainable green campus. Only in realizing the impact of our energy use patterns can we work to change them. By assessing the effectiveness of educational and technological tactics to conserve energy as well as investigating sustainability successes at other schools, informed solutions and recommendations have emerged.
III. Energy Conservation Successes at Other Colleges and Universities

a. Harvard University

Harvard University’s efforts in campus sustainability are exemplary in the organization and effectiveness of the campaign (Harvard Green Campus Initiative 2006A). The Harvard Green Campus Initiative (HGCI) is the overarching sustainability organization on campus (Harvard Green Campus Initiative 2006B). The HGCI started in 2000 and is comprised of professors and administrators. The two co-chairs are Professor John Spengler, the Director of the Environmental Science and Engineering Program, and Thomas E. Vautin, the Associate Vice President for Facilities and Environmental Services for Harvard University (Harvard Green Campus Initiative 2006B). The director of HGCI, Leith Sharp, also co-teaches the Harvard Extension School course, *Sustainability - The Challenge of Changing Our Institutions* (Harvard Green Campus Initiative 2006B).

The HGCI started the Harvard Resource Efficiency Program in 2002 (Harvard Green Campus Initiative 2006C). The main focus of this program is to peer teach students environmentally sound ways of living. The program also involves collaboration of many different organizations on the Harvard campus. These include: Harvard College Environmental Action Committee (the umbrella student organization for undergraduate environmental committees), FAS Office of Physical Resources, University Operations Services, and the Harvard Green Campus Initiative (Harvard Green Campus Initiative 2006C). The resources Harvard possesses contribute greatly to the organization and success of the program. Harvard works in collaboration with other outside organizations to fund 19 students, who are employed as two captains and 17 dorm reps, to continue
efforts to lower dorm energy use (Harvard Green Campus Initiative 2006D). The program costs approximately $90,000 a year. The idea to employ a student in each dorm to educate and carry out dorm energy conservation projects is enlightened. It allows for students to have a connection with the people they are trying to educate and have the most knowledge on how to effect change within their own context. However, many schools do not have the resources to employ so many students in such an effort.

Harvard has experienced success through its Resource Efficiency Program (Harvard Green Campus Initiative 2006A). Harvard worked to change 300 washing machines to more energy and water efficient front-loading machines, saving an estimated $500,000 per year. Harvard is also actively engaged in student led environmental education in dorm rooms. The program representatives visited over 1000 undergrad suites and gave out energy conservation stickers and pamphlets outlining 'green dorm' living. They also addressed dorm heating by teaching students how to turn down thermostats. Harvard estimated that electricity use diminished by 3% during the campaign in the fall of 2003-2004, saving an estimated $45,000. On top of that, the HGCI estimates that heating education has saved $8,000. They are now working toward installing motion sensors in all dorms (Harvard Green Campus Initiative 2006A).

School breaks are a potential time to save the energy that students would normally consume by leaving on appliances. Harvard students seized the opportunity and created a Thanksgiving electricity saving pledge to turn off computers (Harvard Green Campus Initiative 2006A). 20% of the student body participated in the campaign, and it is estimated that these students saved $8500 in that one weekend. This model could be
easily replicated on many different college campuses for a low cost. It has the potential to save energy dollars.

b. Brown University

Brown University started a campus wide greening initiative called "Brown is Green" in 1990 (Brown University 2006). Student researchers work in conjunction with administrators to study and make changes at the campus level, coordinated by the Resource Efficiency Manager. Initially the Brown is Green program employed an Environmental Coordinator who coordinated sustainability initiatives. The nature of the position has evolved to become a Resource Efficiency Manager and Adjunct Lecturer. The Resource Efficiency Manager reports to the Vice President of Facilities Management (Brown University 2006). Through these initiatives, Brown increased energy efficiency. In 1994, Brown upgraded 265 motors to high efficiency motors. Brown also upgraded lighting in some dorms and academic buildings by working with the EPA's Green Lights Program (Brown University 2006).

A class at Brown in the academic year 1994-95 created a model where the classroom became a space for direct action (Brown University 1994). This model of class-based action has been replicated many times at Brown (Brown University 2006). Nineteen students and one teaching assistant conducted a light study at Brown University in 1993 (Brown University 1994). Their study, "Don't Be Kept in the Dark-Dorm Room Lighting at Brown University," sought to find out more about student dorm electricity consumption, particularly regarding lighting. They wanted to find out how students viewed their current lighting in dorms, and whether or not the level of brightness influenced how they used extra lighting. Brown students found out that Brown spent
more than 4 million dollars on electricity each year, 39% of which is consumed by dorm lighting. Students conducted a survey in eleven dorms, distributing 30 surveys randomly in each dorm. The dorms were chosen to incorporate dorms that had been renovated and had newer lighting technology installed, dorms that will be renovated soon, and newly constructed dorms. Students also gauged the lights using an illuminator to measure brightness (Brown University 1994).

Overall, they found that dorm room lighting provided by the university was not bright enough for working conditions, and the majority of students supplemented at least two additional lights in their dorm rooms, mainly using incandescent bulbs (Brown University 2004). Students found that in dorms where lighting was more appropriate for working, use of supplementary lighting decreased significantly.

The class made recommendations for future university light initiatives (Brown University 1994). First, they recommended that incoming freshmen be educated about use of environmentally responsible supplementary lighting, for example purchasing compact fluorescent bulbs. The class sent a letter to the Dean of Students requesting that a pamphlet be included in dorm room assignments that were sent to each student over the summer addressing the importance of purchasing compact fluorescent bulbs for additional lights. The class also advised Brown to provide more light fixtures with brighter lights when renovating or building new dorms. They also outlined which dorms required new lighting the most. They discussed in the future the possibility of selling compact fluorescent bulbs at a discounted price or providing each room with one free lamp (Brown University 1994). The results of their work are not available online; it appears that other more recent student projects have worked to provide first years inserts
in their dorm assignment mailings to encourage students to buy compact fluorescent bulbs and other energy star appliances. Brown student groups have also worked to make these appliances available at the bookstore (Brown University 2006B). Because of the class-based action and availability of the preliminary studies online, it is difficult to assess the long term effectiveness of these student efforts.

c. Oberlin College

Oberlin College has a strong Environmental Studies Program and a student led group, Climate Justice, which network within and beyond the college in their greening initiatives (Oberlin College 2006A and 2006B). In 1999, Oberlin built the Adam Joseph Lewis Center for Environmental Studies, which has become a model in ecological design (Oberlin College 2005B). This building is an experiment for Oberlin. It has over 150 built in environmental sensors with photovoltaic panels, a living machine that filters gray water, and meters that make electricity use data available in real time. The building is used for environmental education of the college community and local schools as well as college students. It also provides an experimental building for forms of alternative energy and energy education. Its energy use is more than half the Oberlin building energy use average (Oberlin College 2005B).

Oberlin College students participated in the first ever Environmental Protection Agency’s P3 Competition and won first prize in 2005 (Environmental Protection Agency 2006). The project was spearheaded by a senior honors thesis student and his advisor. They partnered with the student run Climate Justice Group (Oberlin College 2006A). This partnership created its own data monitoring and feedback system for dorm energy consumption at Oberlin with EPA funding. It was a collaborative effort among faculty
and students (Environmental Protection Agency 2006). The dorm energy competition took place over a two-week period between March 10, 2005, to March 24, 2005. Overall, 68,500 kwh were saved, which translated into $5,120 in savings for the college. Most dorms could access their electricity consumption data through low-resolution information; however two dorms could access their data in real time through a wireless sensor network that was installed in the two dorms (Environmental Protection Agency 2006).

The two dorms that could access the real time electricity consumption data (broken down by floor) experienced much greater electricity use reductions than other dorms (Environmental Protection Agency 2006). The other twenty dorms received low resolution information on campus wide reductions in electricity. Low-resolution data were information on electricity use that was updated periodically, not current electricity use like the real time data. Those students living in the two real time electricity consumption dorms cut electricity use by 55%, and those living in other dorms cut electricity use by an average 13%. By making the information available online, many students were able to access the websites. Over the two-week period, they had 4,082 hits from 1,036 different computers (Environmental Protection Agency 2006). By making information available online, many students became interested in their electricity use and could view it easily online. This system allows students to reconnect with the amount of electricity they use.

Oberlin is currently developing a Campus Resource Monitoring System as part of the Phase Two funding by the EPA P3 program, "People, Prosperity and the Planet" to make real time data available for all of the dormitories. The website breaks down electricity...
use by dorm and by person, comparing it to the college average (Oberlin College 2006A). The Oberlin College website also rates the dorms by the amount of electricity they use (Oberlin College 2006A). This public dorm ranking of electricity use creates a transparency of electricity use because all students know how much electricity each dorm uses. Oberlin found that a level of social and environmental responsibility arises for highly consumptive dorms once their consumption levels become public knowledge. Oberlin’s example demonstrates the potential electricity saving that could occur at Colby by placing dorm electricity use on the internet for student viewing. The availability of real time data was much more effective. However, Oberlin was able to develop the technology through substantial outside funding, which is difficult to receive (Oberlin College 2006A).

d. Bowdoin College

Bowdoin College has its own Sustainability Office that works with the Facilities Management (Bowdoin College 2006A). This office employs a sustainability coordinator and student workers. They also organize student subcommittee groups; there are groups that focus on energy conservation, bikes and recycling/waste reduction (Bowdoin College 2006B). Bowdoin has built two dorms that are LEED certified (Bowdoin College 2006C). The design of these includes geothermal heating, individual thermostats, large windows and skylights, and a rainwater catchment system (Bowdoin College 2006C).

The Sustainability Office and Facilities Management at Bowdoin College run a dorm electricity saving competition each year (Bowdoin College 2006A). Begun in 2002, it used to be a week long competition, but in both 2004 and 2005 the competition was extended to a month (Bowdoin College 2006D and 2006E). They promoted the
competition through emails, flyers around campus, and announcements on the campus radio station. Education in the residence halls, where Resident Advisors work in conjunction with the Facilities Management, is also included. Working with RA's is similar to Harvard's conservation approach described earlier. They recommend how to conserve electricity. Tips they give include buying compact fluorescent bulbs, turning up refrigerator temperatures, shutting off appliances and proper computer use (Bowdoin College 2006A).

In 2004, the 19 dorms averaged a reduction of 24.69% of electricity use (Bowdoin College 2006D). The total savings were 71,281 kwh. This translates to saving $6,340 and reducing carbon dioxide emissions by 106,922 pounds. The winner of the dorm competition was determined by comparing how much electricity each dorm used before the competition compared to the electricity used during the competition. The top dorm received a $200 prize and the second dorm received $100 (Bowdoin College 2006D). Bowdoin repeated the dorm competition in 2005 resulted in 38,768 kwh of savings during the month of October (Bowdoin College 2006E). The reductions in 2004 were noticeably larger than 2005. The report speculated that construction occurring next to the dorms was using electricity that was metered by the dorms. Dorm energy competitions have the potential to educate and involve many students, and decrease electricity use in the short term. It is difficult to determine long term effectiveness of dorm electricity competitions, often many people switch back to old patterns. However, the awareness dorm electricity competitions raise is incredibly positive.
Tufts University

Tufts University Institute for the Environment began in 1998 to oversee environmental research and outreach on all of Tuft's campuses (Tufts University 2001). The Institute for the Environment created the Tufts Climate Initiative (TCI) (Tufts University 2006A). The TCI employs three staff and has two faculty members on it. It has created partnerships with the Tufts Division of Operations and the University College of Citizenship and Public Service (Tufts University 2006A).

Tufts spearheaded energy conservation, particularly in lighting. In 1990, they were the first university or college to sign the EPA's Green Lighting pledge, which committed them to upgrading 90% of their floor overhead lighting. In 2001, Tufts invested in upgrading buildings by installing compact fluorescent bulbs and motion sensors. They estimate in the 14 buildings they have renovated since 1990 that $91,930 dollars has been saved after the initial payback period of 2.5 years (Tufts University 2006B).

TCI sponsors a compact fluorescent light bulb (CFL) exchange; all faculty and students can exchange their incandescent light bulbs for free CFLs (Tufts University 2006C). As of the summer of 2005, Tufts has handed out over 3,000 bulbs as part of its compact fluorescent exchange program. One CFL uses 25% of the energy one incandescent bulb does (Tufts University 2006C). CFLs last as long as nine incandescent bulbs, or up to seven years (Tufts University 2006C). The Phillips CFL bulbs that were exchanged at Colby last for 12,000 hours of use.

Tufts uses brochures to educate on many energy saving topics. They distribute a computer brochure to all students, faculty and administrators that has green computing tips as well as compelling figures on energy waste (Tufts University 2006D). They
advocate for turning off screens when not in use as well as setting the computer to a
power saving mode (Tufts University 2006E). The Tufts Climate Initiative is currently
investigating with the Tufts Information Technology Office the possibility of turning off all computers at night through a central server.

IV. Methods

Multiple methods were used to gather data about dorm energy use patterns and student attitudes regarding energy conservation techniques for this thesis project. The primary source of data for energy use patterns is the energy use survey created for this study that was available to the whole student body (Appendix A). The dorm energy experiment generated data on student responses to energy conservation treatments and dorm energy use. Various energy conservation methods were implemented for treatment dorms and compared to control dorms that received no additional attention. These methods include education and technological approaches to energy conservation. These methods are broken down into four phases of implementation that will be outlined in greater detail later in this section of the paper.

a. Energy Use Survey

A survey was designed to determine student energy use patterns at Colby (Appendix A). This information is important because to work to save the most energy, it is important to know and quantify student energy use behavior. Students in the Environmental Studies Program in conjunction with the Environmental Advisory Group created an environmental attitudes survey two years prior to this study. This survey along with an energy survey created by students at Brown University provided a general
framework for the construction of the student energy use survey created for this project (Brown University 1994).

The objective of the survey was to gain an idea of the typical student's energy consumption pattern in their Colby dorm room. It also was designed to make people more aware of their appliance use and energy use patterns. In that sense, the survey was a form of environmental education in and of itself. By asking questions about sharing appliances or how many hours one leaves the computer on without using it, the survey pointed out areas of electricity waste. 582 students filled out the survey. Many students on campus responded positively to the survey, saying that it caused them to reexamine their habits.

The process for submitting a survey at Colby has multiple steps. An institutional review board with professors from different departments oversees any research involving human subjects. After they approved it, the survey was submitted to Information and Technology Services (ITS) to make it available online. Online availability made the survey accessible to all Colby students. All results from the survey were downloaded in Microsoft Excel, which facilitated an organized collection of responses and analysis of results.

The survey was available to all Colby students at the beginning of February and remained accessible until the beginning of April. Many techniques were utilized to try to obtain the largest sample pool possible. The target number was 500 students, which was deemed an adequate sample size for Colby (enrollment on campus of 1821 students). Environmental Studies and other supportive faculty were asked to send an email link to their students. The survey link with various messages was posted on the Digest of
General Announcements several times a week. The digest is sent to all students each day. Initially, each post gained many new people, but after a few weeks participation lagged. Incentive prizes, such as a ten dollar gift certificate to Waterville House of Pizza or Pad Thai once a week, were awarded once a week. Only a certain part of the population at Colby reads the Digest of General Announcements, so participation stopped increasing as Digests continued. The student government also has the ability to send out individual emails to the whole student body. The Digest emails are a list of announcements, but the student president’s emails only have one topic at a time. The president of the student body was contacted and requested to send an email with the survey link and description in it. This action proved very effective, yielding an additional 148 participants. The survey sample size was 582.

b. Design of Experimental Dorm Study

The experimental dorm study was designed to assess the effectiveness of energy saving technologies and education in dorms at Colby. The experiment provided a small cluster of dorms to test potential campus wide efforts. The effectiveness of these treatments was measured by metering electricity use in dorms, and comparing the electricity use of the treated dorms to the electricity use of the unaltered dorms. Electricity monitoring or use problems became more apparent during each step. The study was also attractive because it provided a new purpose to the recently installed electricity meters and ensured that the data would be saved and analyzed.

Since dorm meters were recently installed in all dorms on the Colby campus except for five dorms located on frat row, previous dorm electricity use data were not available (DeBlois, pers. comm.). Consequently, control (untreated) and experimental (treated)
dorms of similar sizes and year of renovation were selected. Four experimental and control pairs (eight dorms) were selected (Table 1). The four dorm pairs were: West and East Quad; Marriner and Leonard; Averill and Johnson; Goddard-Hodgkins and Treworgy. Once these four pairs were determined, each pair was divided into a control and an experimental dorm. A survey of the dorms was then conducted to determine what major appliance and structural differences each pair had. No major differences that would effect the electricity metering were discovered.

Table 1. Dorm survey and inventory information of four experimental dorm design pairs: (1) Goddard-Hodgkins and Treworgy, (2) East and West Quad, (3) Averill and Johnson, and (4) Leonard and Marriner.

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<th>Dorm</th>
<th>No. of Dorm Rooms</th>
<th>No. of People</th>
<th>Square Footage</th>
<th>No. of Common Bathrooms</th>
<th>No. of Faculty Lounges</th>
<th>No. of Heating Zones</th>
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<td>Goddard-Hodgkins*</td>
<td>11</td>
<td>30</td>
<td>8,160</td>
<td>3</td>
<td>one</td>
<td>2</td>
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<tr>
<td>Treworgy</td>
<td>17</td>
<td>37</td>
<td>8,160</td>
<td>3</td>
<td>one</td>
<td>2</td>
</tr>
<tr>
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<td>118</td>
<td>23,155</td>
<td>8</td>
<td>one</td>
<td>2</td>
</tr>
<tr>
<td>West Quad</td>
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<td>104</td>
<td>22,704</td>
<td>7</td>
<td>one (two people)</td>
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</tr>
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<td>14,530</td>
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<td>1</td>
</tr>
<tr>
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<td>61</td>
<td>14,530</td>
<td>7</td>
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</tr>
<tr>
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</tr>
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<td>43</td>
<td>14,000</td>
<td>2</td>
<td>none</td>
<td>2</td>
</tr>
</tbody>
</table>

*Goddard-Hodgkins is the Green House

Goddard-Hodgkins and Treworgy

Goddard-Hodgkins is the 'Green House' on campus. The Green House is in their first year of existence. It is an experimental dorm where all members work to minimize their environmental impact, have dorm meetings each Sunday, and organize environmental...
awareness activities on campus. The philosophy of the dorm made it a perfect candidate to be one of the experimental dorms of this study. The Green House took measures to conserve energy and water before the experimental work of this thesis. They have lamps available in the common space, and often choose to use them instead of overhead lights. They have motion sensors in the bathrooms. Drying racks set up in the laundry room serve as an alternative to energy consuming hot air dryers. Residents also keep fewer lights on in the dorm. They also have agreed upon a lower heating temperature for the dorm during winter months than other dorms. They try and keep the upstairs and downstairs lounge overhead lights off. They have water toggles on all showers for users to soap up without using water, but allowing the water to remain hot.

Treworgy is the control dorm for the Green House. Treworgy is located across the quad with a comparable size and number of students (Table 1). Both dorms were built at approximately the same time. Both dorms have their heating broken into two zones that are divided into east and west sections (Mayo, pers. comm.). Each heating zone is operated by one thermostat located in a dorm room in that zone.

**East and West Quad**

East Quad is the experimental dorm and West Quad is the control dorm. East has 14 more students than West Quad, which is the largest difference in student number of all the pairs (Table 1). While both dorms have four floors, East's basement floor also has dorm rooms. East Quad is also speculated by PPD to use more energy in heating because the basement floor loses much more heat than the rest of the floors (McCutcheon, pers. comm.). Both dorms have their basement floor exposed to the pond, and it is speculated they lose heat because the wind is strong in that area and they are exposed. West Quad
loses less energy because no residents live on the basement floor of West, whereas they
do in East. East Quad was selected as the experimental dorm because it has more
residents than West Quad. While the results are broken down to a per person basis, the
larger experimental pool of students creates a greater possibility for response to the
educational and technological methods.

**Averill and Johnson**

Averill is the experimental dorm and Johnson is the control dorm for this pair. Both
were renovated within a year of each other. They both have a high number of heating
zones because newly renovated dorms have many more heating zones (Mayo, pers.
comm.). These two dorms are so similar in size and year of renovation that the
experimental and control choices were made arbitrarily (Table 1).

**Marriner and Leonard**

Marriner and Leonard are the fourth pair. Marriner is the experimental dorm and
Leonard is the control dorm (Table 1). These two dorms are connected, so heating in the
two dorms is shared. Marriner was chosen as an experimental dorm arbitrarily as well.

**Phase I: Dorm Alterations for Experiment**

The Physical Plant Department installed energy saving technology in three of the four
experimental dorms in the first week of February (Table 2). Multiple meetings were
scheduled with director of PPD Patricia Murphy and Environmental Program Manager
Dale DeBlois to plan out motion sensor installment. Head Electrician John McCutcheon
was consulted numerous times prior to his retirement and Craig Shores installed all the
sensors. Craig placed motion sensors in lounges, bathrooms, and the laundry room.

Vending mizers were placed on vending machines.

All planned motion sensors were successfully installed in East Quad and Marriner. The Green House had already contacted PPD over the summer to have bathroom sensors installed and set to 10 minutes. Unlike other dorms, the Green House residents keep all the hallway lights, stairway lights, lounge lights and entry way lights turned off most of the time. They leave one entry way light on during weekend nights. When people study in the lounge during the week or weekend they have overhead lights on.

Table 2. Number and location of dorm sensors and vending mizers installed in experimental dorms.

<table>
<thead>
<tr>
<th>Dorm</th>
<th># of Lounge Sensors</th>
<th># of Bathroom Sensors</th>
<th># of Laundry Room Sensors</th>
<th># of Vending Mizers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goddard-Hodgkins *</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>East Quad</td>
<td>1</td>
<td>8</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Averill</td>
<td>4</td>
<td>none</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Marriner</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

* Green House sensors were installed before this experiment began.

All planned motion sensors were not installed in Averill. It was planned that bathroom light sensors would be installed on each floor. The bathroom light wiring in Averill goes through room walls, so sensors could not be installed without breaking through a dorm room wall. This was not economically feasible so bathroom sensors were not installed.

Averill was recently renovated. The lighting in both Averill and Johnson and in other newly renovated dorms is different from older dorms. In the hours from 4-10 pm, all lights are on. In the off-hours outside of that time period, every other light is on. This is done through wiring and cannot be changed in other dorms until renovation, unless it
becomes a priority in the summer months. This is a model used by Colby that reflects the growing trend of energy efficiency throughout the dorm building and renovating process.

**Phase II. Environmental Education**

Energy education was part of the experimental design to target energy use levels in dorms that can be lowered by behavioral changes. Some students do not want to change how they live in dorms, but many are unaware of how much energy they consume and what easy steps they can take to lower their energy use. The environmental education program had four parts: (1) The Turn Off Appliance Sheet; (2) The Computer Use Sheet; (3) Heating Information Sheet; and (4) Green Living and Purchasing Guide.

Dorm energy education began with the initial compact fluorescent light bulb exchange. All students who exchanged bulbs or chose not to were told about the bulb exchange, the possible energy savings, and the objective of the thesis. They were not informed that they were being compared to control dorms. They were not told the period that their dorms, the experimental dorms, would be monitored for electricity use. They learned that environmental education would be provided and dorm electricity consumption would be monitored. While these conversations were informal and short, they allowed the students to grasp that this was a student run study and gave them the space to think about how their living style could contribute to the study. Many students were curious about the bulbs and supportive of the effort.

Dorm energy conservation postings lasted for a four-week duration. A different poster or informational sheet was added each week. The education began mid February and continued through the middle of March. The first poster that was put up was
designed to stand out (Appendix B). Multiple copies were put on each floor of the four experimental dorms. They were placed so that each resident would see at least one whenever he/she left his/her room. The poster was designed so that the first poster would not have too many facts or written text, but instead start off on a simpler note. The sign read, "Stop. Think About it. Are your lights and appliances turned off??" (Appendix B).

Computer energy saving techniques were distributed to the experimental dorms the next week (Appendix C). Because this sheet has a lot more text, a sheet was placed on the inside of each bathroom stall. One guaranteed place in a dorm to place informational sheets to be read is inside bathroom stalls. The information from the sheet was derived from the Colby Green Computing tips, which are available on the Colby Green webpage (http://www.colby.edu/green/documents/GreenComputing.pdf) as well as the Colby ITS webpage (http://www.colby.edu/info.tech/green/).

The energy computers use in comparison to local New England states was highlighted in the first paragraph of the sheet. The rest of the sheet provided steps students could take to use their computers more energy efficiently. Since 99% of the 582 surveyed have computers, this sheet was potentially influential. ITS estimates that 95% of Colby students own personal computers (Phillips, pers. comm.). It stated that if a computer idles over 16 minutes then it would use less energy to turn it off. The sheet also suggested behavioral changes, such as grouping computer use times into certain sections of the day, and checking one's email at the college's libraries, since computers are always on in those areas. The sheet also explained the most efficient way to leave a computer on is standby mode, with the monitor off. The monitor screen saver is commonly misconceived as an energy saver, although it is not.
Various students reacted positively to this sheet. A few said that it changed how they conducted their days, and that they had not been aware of proper computer energy management practices before reading the sheet. Other responses echoed those sentiments of lack of computer energy saving awareness in the open response on the survey. One clear implication of the study is that it is important to educate the Colby community about computer use. This thesis found that a large number of people were not aware of proper computer energy saving techniques.

The third piece of dorm education was a sheet adapted from a PPD information sheet that is distributed to all students at the beginning of each year. This sheet was also filled with text, so it replaced the green computing sheet in the bathroom stalls. This sheet, titled "The Cold/Hot Dorm Room Breakdown," informed students how dorm heating functions and the measures they can take to fix dorm rooms that are either too hot or too cold (Appendix D). The sheet had the student check out possibilities for the room being too hot or cold. For example, a hot appliance located next to the thermostat would cause the sensor to provide less heat to the room because the room registered as artificially warm. The sheet also advised against opening up windows during winter months to cool hot rooms, because much energy is wasted.

The last piece of dorm education is the Green Living and Purchasing Guide hung up in the bathrooms next to the mirror. The poster has 10 sustainability tips, sustainable living information, green computing directions, and energy star appliance information (Appendix E). It was chosen as the last piece of dorm education because it is the most holistic of the education sheets and a good sheet to end the education section.
Phase III. Compact Fluorescent Light Bulb Exchange

Inspired by a visit from Sarah Creighton of Tufts University, part of the experimental dorm project included distributing compact fluorescent bulbs in exchange for incandescent light bulbs that students may have in their dorm rooms. The Philips 14 watt Marathon compact fluorescent bulbs used in the Colby exchange are 66% more efficient than incandescent bulbs and are guaranteed to last for 12,000 hours of use. Funding was made available by Vice President for Administration Douglas Terp and the bulbs were purchased by PPD.

Each experimental dorm was visited and compact fluorescent light bulbs were exchanged for incandescent bulbs. East Quad exchanged 37 bulbs. Averill exchanged 20 bulbs. Marriner exchanged 11 bulbs. The Green House exchanged 12 bulbs. Many residents in the Green House probably had these bulbs already. These numbers reflect the cooperation of many students in each dorm. They are also reflective of the day and time the dorm was visited, because that dictated participation. Many doubles and triples were supportive but only took one bulb. A few students declined to accept the free bulbs in each dorm. The primary reason for these students was that they did not need any compact fluorescent bulbs. A few students did not want the bulbs even though they did have incandescent bulbs to swap. Each dorm was only visited once for the light bulb exchange. This occurred for a variety of reasons. After each dorm had been visited once, the light bulb supply at PPD depleted. Reordering was problematic. First the wrong size bulbs were sent; then the correct size was backordered and took a few weeks to arrive.

Another focal point for the light bulb exchange was administrative and faculty offices, because faculty and staff spend so much time in their offices and are in their
offices for working purposes, which often necessitates a small lamp. Although this exchange obviously had no affect on the analytical outcomes in this thesis, it presumably did result in energy savings and perhaps some consciousness raising.

Two sizes of light bulbs were used in dorm and administrative buildings. The 14 watt light that is the same size as the normal incandescent bulb was given out in all dorms but Marriner. This means 69 of the 14 watt bulbs were given out in Averill, the Green House and East Quad. Some 20 watt light bulbs were used because they were stocked in the PPD store room; however these proved to be incompatible with many light fixtures designed for the average sized incandescent bulb. The 14 watt bulbs are roughly the same size as typical incandescent bulbs, and the 20 watt bulbs are an inch or so longer. The 20 watt bulbs also use more energy and emit more light than most people require while working. However, these were the only bulbs in stock for awhile.

Eventually, as mid March approached and more 14 watt bulbs were not in stock or available from the supplier, the compact fluorescent bulb exchange in the experimental dorms ended for this year. Compact fluorescent bulbs exchanged in academic and administrative offices have a much better chance of being used in those offices for years. Staff and faculty are less likely to move their lamps and remove the bulbs. Bulbs exchanged in dorm rooms may not return with students the next year. The bulbs exchanged in dorm rooms two months before the end of the year do not have as promising rate on continuation past their use this year. It is important that a compact fluorescent light bulb exchange occur again at Colby, via a free exchange or bulb availability on campus at a discounted rate. The energy use survey results indicate there is student interest in a compact fluorescent light bulb exchange in the future. 92% of the
students surveyed said they would exchange an incandescent for a free compact fluorescent. Approximately two-thirds of the students surveyed (62%) said they would exchange an incandescent for a reduced cost compact fluorescent.

The administrative payback for exchanging 104 bulbs with faculty and staff was calculated based on an annual basis and on the life cycle of the bulbs, since I believe that most bulbs will remain in the offices for an extended period. The annual energy savings for this bulb exchange is projected to be $1,674 (minus the bulb cost of $1040 in the first year) assuming four hours of use per day. Longer use would result in more savings. The life cycle cost for 104 compact fluorescent bulbs is $3,173 (Energy Star 2006). The life cycle cost for 104 incandescent bulbs is $18,276. The savings over the 104 compact fluorescent bulbs' lifetime is approximately $15,000 and the payback period is 0.4 years (Energy Star 2006). The life cycle cost calculations are based on the Energy Star calculator, which incorporates maintenance costs. The CFL bulbs will save $634 in the first year alone, including paying back the bulb cost. The savings for the compact fluorescent bulb exchange during dorm experiment was calculated for the three months the lights were used during the study. The cost for the compact fluorescent bulbs was $800. The payback in the three months used in terms of energy saved was $483 assuming six hours of use per day (Energy Star 2006). On an annual basis, the savings for the year compared to incandescent bulb use are projected to be $1,132 ($1,932 in savings – CFL bulb cost of $800).

If 92% of the students (1625 students), participate in a compact fluorescent bulb exchange next year and used their bulbs for 6 hours a day, approximately $2,800 would be saved over the academic year (eight months) by a free compact fluorescent bulb
If 62% of the students (1125 students) participated in a 50% discount sale of CFL bulbs, then the savings would be approximately $12,500 (Appendix G and Appendix H) (Energy Star 2006).

The exchanged incandescent bulbs are still functioning, but it was decided they will be part of a recycled art project. The light bulbs form the trunk of a recycled art tree that was part of the Earth week recycled art competition. The light sculpture, titled "Leave a Brilliant Phootprint," won best use of recycled materials. The art exhibit remained in the Green House lounge for the remainder of the school year. An informational sheet was attached to the sculpture describing the benefits of compact fluorescent bulbs and the number exchanged at Colby. This became an additional component of the energy conservation education.

Phase IV. Model Dorm Room

The main project of the Energy Subcommittee was to create a model dorm room. Students Kerry Whittaker ('08), Rose Becker ('08), Jamie O'Connell ('08), and Jenny Venezia ('06) worked for Professor Russ Cole to gather data on the energy in kilowatt hours that different dorm appliances use. They used a Watts Up? PRO, a meter that measures electricity use and converts the physical consumption data into an economic cost. Their results were used in creating the model dorm room with a sustainable roommate and a non-sustainable roommate (Figure 1). The practices of the sustainable roommate ranged from using compact fluorescent bulbs to a drying rack. The sustainable roommate also had a notebook computer, with details about energy management practices.
The dorm room set up was placed in a rented trailer outside of the student union during Earth Week (Figure 1). Each appliance in the dorm room was labeled with its kilowatt hour usage and monetary cost associated with it. Highly consumptive appliances were labeled with orange paper, and the alternative appliance that used less energy was labeled in white. Inviting music was played outside the trailer and local foods were used to make grilled cheese sandwiches for those who walked through the trailer. Informational sheets on green living tips and energy conscious actions were available. Energy Subcommittee members were available all day to give tours and explain more about the exhibit. The turnout for the model dorm room was large and

Figure 1. Model dorm room exhibit with Energy Subcommittee members Kerry Whittaker ('08) and Liza Mitchell ('08) during Earth Week.
many people were enthusiastic about the exhibit.

The trailer was subsequently used as part of a local high school energy conservation education effort. It is an informative exhibit for students to come and learn about energy conservation practices before they purchase appliances for their own college dorm rooms. It is also part of Colby's active campaign to create more connections with Waterville and the surrounding area.

V. Survey Results and Discussion

The energy use survey generated a wealth of data. The data established student energy use patterns. The survey also asked students to share their concerns and ideas for energy conservation at Colby, particularly in the areas of heating and lighting. 582 students participated in the survey. I believe this is an adequate sample size to be representative of the Colby community.

Computer Use

Computer use in dorm rooms is one of the largest areas of energy use and also one of the biggest target areas for reducing energy use. 99% of students surveyed have a computer in their dorm room. Ray Phillips, directory of Information Technology Services at Colby estimates that 95% of Colby students own their own personal computer (Phillips, pers. comm.). This difference in percents is probably a result of the energy use survey being available online, so students who owned their own computers were more likely to participate in the survey. This high proportion of the student population makes the issue of green computing important for the Colby campus.
The survey indicated that there is a gap between the amount of time students use computers to perform activities and the amount of time they leave computers on. Computers left on unnecessarily waste energy. 48% of the 574 students who responded to that question leave their computers on for more than 19 hours a day (Figure 2). 84% of the 575 responding students use their computers to perform activities nine hours or less a day (Figure 3). Most students said leaving computers on was their most wasteful energy practice in the open answer section of the survey. 30% of the 571 responses said they sometimes or more often leave their computer on for AOL instant messages to be left. Clearly this gap between the time that a computer is on versus the time used to perform activities demonstrates that computers are a major

![Figure 2. Amount of hours students leave computers on in one day including when the computer is in sleep mode. N=574.](image)

![Figure 3. Number of hours students use their computers to perform activities. N=575.](image)
source of lost energy at Colby.

Computers are so numerous on the Colby campus that this is an important issue. The responses from those living in the experimental dorms that had never thought about their computer use patterns were an indicator of the situation for the broader Colby community. Computer use is an area for energy conservation action at Colby.

On the positive side, many students are aware of the sleep function on their computer. 56% of the 572 respondents always or frequently put their computer to sleep after it has not been used for 30 minutes. On the negative side, 26% never or rarely put their computer to sleep when they have not used it for 30 minutes. The time lapse before a computer goes to sleep differed. 37% of the 539 students taking the survey said their computers go to sleep in 15 minutes or less. 28% of the students responding said their computers go to sleep after 30 minutes. 18% stated that their computer never goes to sleep. 66% of the 572 respondents never or rarely turn their computer off after 30 minutes of use. In summary, many Colby students put their computers to sleep, 65% in 30 minutes or less, which is less energy consumptive than simply leaving their computers on in full power mode. However, many Colby students still leave their computers on for longer amounts of time than they should when the computers are not in use.

Tufts Climate Initiative produced a brochure that outlines how much energy could be saved by changing computer practices (Tufts University 2006F). TCI estimates that 3000 Tufts students own personal computers. They calculated how much energy could be saved if every student turned off their computer for six hours a day for the whole academic year. In one year, 788,400 kwh of energy would be saved, which would in turn save $87,000 and reduce emissions by 572 tons of carbon. (Tufts University 2006F).
Conversely, they calculated that leaving on one computer 24 hours a day all years costs $115 annually and puts 1500 lbs of carbon into the atmosphere (Tufts University 2006F).

Estimates of different computer use patterns and their resulting kwh and energy costs were calculated by Ray Phillip in a 2002 ITS study (Appendix I). It would cost $816,615 if every computer was left on 24 hours a day with screen saver and $323,553 if every computer uses screen saver but is turned off over night. It would cost $167,035 per year if every student personal computer uses sleep mode but is always turned on. It would cost $144,764 if every computer uses sleep mode but turned off at night. These figures are based on each computer having a CRT monitor.

Computer energy use is declining in recent years due to more efficient computers that Colby and the students are purchasing (Appendix J). For the graduating class of 2006, 50% of all student owned computers are estimated to be notebooks, and 50% are estimated to be desktop (Phillips, pers. comm.). The first years, the class of 2009, have 60-70% notebooks and 30-40% desktops (Phillips, pers. comm.). Notebooks are much more energy efficient than desktops. These desktops mostly have LCR (flat panel screen) monitors, which are much more efficient. It is estimated that 50% of seniors have CRT monitors, but few first years have CRT monitors (most have flat panel screens), so trends of computer energy use are declining. A 17" LCD (flat screen) display consumes 51% as much power when on as a 17" CRT. 15" LCD displays consume 30% as much power as 15" CRT display. Notebook computers use approximately two-thirds less electricity than integrated desktop computers with CRT monitors ($1.08 vs. $3.14 daily consumption in kwh, respectively) (Appendix J).
In light of these findings, some recommendations are: 1. Always purchase Energy Star rated computers and printers; 2. Set college computers and encourage students to set computers to go to sleep in 15 minutes manufacturer default recommended by EPA; 3. Educating computer users that shutting down the computer does not wear it out; 4. Switching to flat panel displays is more energy efficient than CRT of the same size; and 5. Never use screen savers.

**Lighting**

Dorm room lighting is another area implicated by the survey as potentially wasteful. Student use of lighting during weekdays and weekends does not tend to differ (Figures 4 and 5). 76% of 578 responses indicated dorm room lighting was used 4-12 hours per day during the week and on the weekend. 38% of the 572 student responses indicated they are never or rarely able to do school work using Colby dorm room lighting, and another

![Figure 4. Student light use during a typical day of the academic week. N=578.](image1)

![Figure 5. Student light use during a typical day of the weekend. N=579.](image2)
25% said they are only sometimes satisfied with dorm room lighting for work purposes (Figure 6). 46% of 570 respondents always or frequently work with their extra desk lamp on but their overhead light turned off. Students that use their desk lamp and overhead lamp simultaneously frequently use more energy than they need to work and not strain their eyes.

Students indicated in the survey open response section that they are discontent with installed lighting for three particular reasons: inadequate illumination, poor location, and excessive brightness. Colby PPD states that dorm room lighting is not designed to be adequate for optimal working conditions. 121 students responded that their dorm rooms are too dark or dim. Many indicated that Heights dorm is the darkest dorm. Another 26 wrote that it is not that dorm lighting is too bright or dim, but that it is placed inconveniently for working. Most student desks are placed against the walls, and most dorm room lighting is placed in the center of the ceiling. This placement creates a shading effect on the workspace no matter which wall the desk is placed against, particularly at night when there is no natural light. 48 students commented that the fluorescent light quality is too bright or harsh and irritates their eyes or gives them headaches. Multiple responses compared the lighting to prisons or hospitals. Two problem areas uncovered by the energy survey are (1) Dana and AMS

Figure 6. Student responses to how often dorm lighting is adequate for school work. N=572.
suites cannot turn off the common room lights in their dorms because there is no switch and (2) many rooms in Heights have no overhead lights.

As far as awareness and action to turn off lights, many students are engaged in turning lights off when not in use, which is positive. In the open response question, "What is the most energy saving action you take?" the largest response was turning off lights. 90% of the 579 students responded that they always or frequently turn off their lights when they leave their apartment or dorm room. Students indicated in the survey that they are not as vigilant about turning off lights in common spaces. This indicates that motion sensors in dorms are a positive installation. Only 62% of 580 responses claim they turn off common space lights when not in use.

The issue of extra lights is quantitatively important because 99% of the 571 students taking the survey have at least one incandescent bulb in their dorm room (Figure 7). 55% have more than three incandescent bulbs in their dorm room. This fact makes the population that could potentially use compact fluorescent light bulbs large.

A compact fluorescent light bulb exchange similar to the one initiated at Tufts could work effectively at Colby. 92% of the 575 responses said they would participate in a free compact fluorescent light bulb exchange, if presented with the opportunity. In contrast, only 62% of the 575

Figure 7. Number of incandescent bulbs each student owns in dorm room. N=571.
would participate if the compact fluorescent bulbs were available at a suggested discount price (50% used in the survey). 62% participation of the student body would mean 1129 students exchanged bulbs, but much more energy could be saved by 30% more participation.

**Heating**

From the survey, it appears that a considerable number of students are discontent with their heating. Dorm heating at Colby is regulated by zones. Dorms are divided into heating zones. One room within that zone is the indicator room for each zone, and this room has the thermostat that controls heat for the entire zone. Consequently, many students commented on the variation in dorm room heating at Colby. For example, contiguous rooms may vary more than 10 to 20 degrees in temperature. 58% of the 579 student respondents said they are never to sometimes content with the heating in their rooms (Figure 8).

Answers to how students would like their dorm heating to change vary, but most students would like more individual control over their room temperature. Approximately 14% of 579 students

![Figure 8. How often students are content with their heating. N=579.](image-url)
surveyed want their room temperature to remain what it is now (Figure 9). 45% want their rooms to be more responsive to the varying temperature outside.

Many of the open response questions addressing what could be done to fix dorm room heating problems requested smaller heating zones or individual room thermostats. Some students had the enlightened idea to enable the thermostats so they could be turned down, but not up. This would help curb window opening and decrease energy use. Many students complained about drafts and needing new windows and/or storm windows, particularly in all frat row dorms, East Quad, and Heights dorms. Frat row dorms have not been renovated, so it is logical that window insulation is lacking. People continually stated that windows were too drafty and much energy was being wasted trying to heat these rooms.

Some students admitted in their open answer section that they do leave their windows open. In the survey, 75% of the 580 responses said they kept their windows open from 0-3 hours a day. This response was based on year long habits, so it included winter months. The other 25% leave their windows open

Figure 9. Student preference for dorm room heating. N=579
over 4 hours per day, and 7% claim they leave their windows open 22-24 hours a day during the heating season. This behavior wastes a large amount of energy.

Students were asked in the survey if they were content with the heating in their dorm rooms. Figure 10 shows these responses by dorm. Many of the smaller dorms did not have as much participation in the survey, so the number of students sometimes to never content with their heating is low. East and West Quad were some of the first dorms renovated, so it is not surprising they have many residents discontent with their heating. The figure does demonstrate that each dorm has students who are discontent with heating a fair amount of the time.

Figure 10. Number of students sometimes, rarely, to never content with the heating in their dorm room. N=579.
Judging by open response answers to heating issues and survey results, heating education can help save Colby money. 28% of the 577 students who replied stated that they were "slightly aware to not aware at all" of the factors that influence heating at Colby (Figure 11). Another 41% admitted being only moderately aware of the heating system at Colby. This means 30% of students are very aware of the factors that influence heating (Figure 11). Awareness does not necessarily ensure windows would stop being opened during the heating season, but it does make it more likely that students would explore other options before opening up their windows to cool rooms down or buying space heaters to warm rooms up. Although space heaters are illegal at Colby, multiple students mentioned using space heaters in the open response section.

![Bar chart showing student awareness levels](image)

Figure 11. Student knowledge of the dorm heating system. N=577.

**Appliances**

In the survey, students were asked to choose all of the appliances listed that they had in their room. The five appliances owned most frequently by students were computers
(99%), extra lights (89%), refrigerators (86%), alarm clocks (80%), and televisions (75%) (Figure 12). Two appliances not listed that students wrote in numerous times were IPODs and cell phone chargers. Although students own many appliances, many claim they often share their appliances with other dorm mates. 57% of the 575 respondents claim they always or frequently share appliances during a typical week. Power cords are prevalent in dorm rooms. Only 25% of the students surveyed claim they have no power cords. 43% said that they have two or more power cords. This reflects the number of appliances students possess and use. Many students requested more electrical outlets in each dorm room.

Students also listed the five appliances they use most (Figure 13). These five appliances were the same five that were most commonly owned. The five appliances ranked from most to least used are: computer (94%), refrigerator (72%), extra lights (58%), television (56%), and the alarm clock (51%).

VI. Results and Analysis of Dorm Energy Experiment

The results of the dorm electricity experiment demonstrated that the treatments to conserve electricity were effective in lowering electricity use for the majority of the experimental dorms. Electricity was expressed by student number living in the dorm. Each pair of dorms received slightly different treatments based on extenuating circumstances. For example, Averill could not have bathroom sensors due to wiring problems. Dorm energy saving treatment constraints allow for different parts of the experiment to be highlighted. Student reactions were positive to the dorm education program. A few students complained of motion sensors in bathrooms because they
Figure 12. Appliances owned by students. N=582.

did not know how the sensors operated. Motion sensors turn the lights off after a certain amount of time, so if a student took an exceptionally long shower then the lights could turn off while that person was still in the shower. This problem can be fixed by waving one's arms around to activate the motion sensor and turn the lights on. To respond to this issue, Head Residents in dorms were contacted and informed how the sensors work. The electricity metering worked well in all of the dorms, but only meters
total electricity use by dorm. Measuring individual room electricity use would be ideal, but expensive to install.

Figure 13. Five appliances used most by Colby students. N=582.

The week from March 24th to March 30th was spring break. This fact explains the decrease in electricity use during that week. It is also interesting because it exhibits in each dorm how much electricity is wasted during break. Students often leave on appliances when they leave for break, which is demonstrated by these graphs. This makes Colby a prime candidate for electricity saving campaigns during breaks like Harvard’s efforts.
Treworgy and the Green House

The first comparison reveals that students who are informed and conscientious really do consume much less electricity. Overall, the Green House was successful in electricity conservation and holding up its ideals as an environmentally conscious dialogue house. Weekly electricity use by per student is shown in Figure 14. There was a statistically significant difference between electricity use in the first six weeks of the study (t-test, df=10, p<0.0056). The Green House's electricity use was much lower than Treworgy's during February and March. Over the whole experimental period, there is no statistically significant difference in electricity use between the two dorms. The Green House did receive 12 bulbs in February. Because the dorm is environmentally focused, it is possible that the dorm education had less of an effect in creating new habits. If students were already working to lower electricity use, then the tips provided in the education may have

Figure 14. Green House and Treworgy weekly electricity use per student
been common knowledge; however, they may have reinforced practices.

**Averill and Johnson**

Averill is another experimental dorm with electricity savings greater in comparison to the control dorm, Johnson. The period when there was the largest differential in electricity use, the middle of February until the middle of March, mirrors the period when the compact fluorescent light bulb exchange occurred and the dorm education was conducted (Figure 15). Because Averill did not receive as many motion sensors, these results suggest that electricity use education and CFL bulb exchange can be effective tools in helping to reduce dorm electricity use. Averill used significantly less electricity than Johnson during the end of February until the beginning of March (t-test, df=10, p<0.0279). This result is similar to the Green House. During the month of April both dorms reached the same level of electricity use. There was no statistically significant difference between the two dorms overall. Student behavior patterns change once the

![Figure 15. Johnson and Averill weekly electricity use per student.](image-url)
weather becomes warmer. Students spend much less time indoors. This fact probably explains the decrease in electricity and minimizing of the gap in electricity use.

**East and West Quad**

East Quad did not use less electricity than West Quad as predicted. The trend for East Quad electricity use was a gradual decline, which either supports the educational and technological efforts to lower electricity use or is related to seasonal change (Figure 16). It is difficult to discern why the educational and technological efforts did not reduce East's electricity use below the level of West's electricity use. East's high level of electricity use compared to West could be attributed to the residents' habits in East being environmentally friendly or not affected by the dorm energy lowering treatments. It is difficult to tell the electricity use patterns of East residents without past data showing East's electricity use. Overall, the difference between electricity uses was not statistically

![Figure 16. East and West Quad weekly electricity use per student.](image-url)
different between the pair, however, West did use significantly less electricity during the end of February until the beginning of March.

**Leonard and Marriner**

Marriner is another experimental dorm that saved more electricity than its control dorm, Leonard (Figure 17). Marriner received eleven motion sensors, which is a large number for a relatively small dorm. Marriner's electricity use decline was gradual. Because Leonard and Marriner are connected, it is quite possible that many Leonard residents were exposed to the education measures. These two details indicate the effectiveness of many motion sensors.

![Figure 17. Leonard and Marriner weekly electricity use per student.](image)

**General Trends and Observations from Experiment**

Marriner, East Quad and Averill all experienced gradually decreasing electricity use. This trend indicates that either the technology and education had a continual effect on the students or the seasonal change. The Green House did not demonstrate a continual
decline in electricity use, but they have been actively working to lower electricity use all year. This sets the Green House apart from the other experimental dorms. Because the education occurred simultaneously with the compact fluorescent bulb exchange and the motion sensor installation, the effectiveness of one method to conserve electricity over another cannot be measured. Both educational and technological methods are strategies for electricity reduction that can and should be implemented in the future to lower electricity use at Colby. The control dorms provided a sound comparison to measure electricity use.

All the dorms greatly reduced electricity use during spring break (March 24 to 31), but they also demonstrated how much electricity is wasted in dorms during break. Based on the per student average of energy wasted during spring break, an estimate was calculated to determine how much money could be saved if electricity was shut off in all dorms during winter and spring break. The average cost in electricity wasted per student for the week of spring break was $3.02. This number was multiplied by 1821 students and multiplied by three weeks (two weeks for winter break and one week for spring break). This means that approximately $16,500 could be saved by turning off all electricity in the dorm rooms during this period.

It is important to continue metering building electricity use so this type of study can be done again. Measures must continue to be taken to retain data rather than overwrite and lose it, as is the current situation. It is also important to monitor the electric metering system so that it is ensured the system is working properly. Unfortunately, the student apartment component of this study had to be scrapped because of a malfunctioning metering system that was not noticed until it was too late.
On a per student basis, the Green House and Treworgy had the lowest in electricity use. East and West Quad also had relatively low electricity use per student. Leonard and Marriner had the next highest and Averill and Johnson had the highest electricity use per student. This outcome shows that the Green House is accomplishing one of its goals as an environmental dialogue house. Marriner, in comparison to Leonard, saved 2058 kwh, which translated to $307 saved based on Colby's 14.9 cents per kwh rate. Averill, in comparison to Johnson, saved 553 kwh saved, or $82. The Green House saved 2226 kwh more than Treworgy, which is $332 saved. The monetary difference between East and West's electricity use was $838. This is not on a per student basis, and there are 14 more students in East. It is important to note that both East and West had lower electricity use on a per student basis than two of the experimental pairs. East has two lounge spaces in basement that could contribute to more electricity use as well. There are too many variables to discern a direct cause to explain East's electricity use being higher than West's.

For future dorm energy experiments and competitions, the greatest difference in electricity use would occur during the winter. This dorm electricity experiment measured less than half of the winter. During the winter, there are less hours of sunlight and students spend much more time indoors. This increases electricity use. A competition would work better in the winter because there is more room for change in habits and energy conservation.
VII. Recommendations for Future Energy Conservation

This thesis work uncovered many energy conservation possibilities and areas for change. Some changes require economic and time investments that are more demanding, while other energy saving efforts will be rewarding with minimal work. The recommendations are listed in order of short term to long term implementation.

**Short Term PPD Action:**

The survey uncovered two pressing issues for PPD to address immediately.

1. **Install light switches in the common spaces of Dana and AMS quads and five-mans.** Dana and AMS quads do not have light switches that control lights for quad common spaces; these lights remain on at all times and residents have no control over these lights.

2. **Create systematic manner to check the seal on all windows in frat row dorms and East Quad before replacement is considered during renovations.** In the open answer section of the survey, all frat row dorms and East Quad reported multiple drafty windows, which waste energy. Windows could be surveyed during the summer and a sealant could be applied to minimize draftiness. As the college looks toward renovation of the frat row dorms, heating control is an issue that should be kept in mind. There are only two heating zones in many of the frat row dorms. This does not allow for heating flexibility or adaptability. A clearer communication could also be set up next year where students, HRs, and PPD staff to work to stop window draftiness in a systematic manner.

**Year Long PPD Action:**

There are other campus wide changes that PPD could take on during the summer months, if there were enough resources and time.
1. Leave only one fluorescent bulb in each overhead light in all dorm rooms on campus. Many students in certain dorms indicated that lighting is too bright, too dark, or placed inconveniently for working. The majority of the students own extra lights and keep them on while the overhead lights on. Most, if not all, overhead lights have two to three fluorescent bulbs in them. PPD admits that light provided in the dorms is not intended to be adequate for working conditions. Since it is an accepted fact that extra lights are normally on, one student in the open answer section of the survey suggested leaving only one light in each overhead fixture. This would minimize energy wasted by students using multiple lights at once and it would be a quick job for PPD.

2. Motion sensor and vending mizer installation in all dorms on campus. Motion sensors and vending mizers pay back their cost quickly. Their energy conservation effectiveness has been demonstrated in many studies. Motion sensors should be installed in all dorms: in bathrooms, lounges, and laundry rooms. Although an easy job to accomplish in most cases, in areas where they require rewiring, this work could be addressed during the summer when it is much less likely the room is being used.

Short Term Student and Administrative Action:

1. First year environmental educational inserts provided in dorm mailing assignments. Educating first year students is an important step to lowering energy waste for the future. If the incoming students can be reached before they begin their appliance purchasing for college and the key foundation for positive college energy use patterns established, it will ensure a promising future for Colby electricity use. Brown students advised the Dean of Students to send a letter to incoming first years about the benefits of using compact fluorescent light bulbs with dorm room assignments. Colby already sends
the Green Living and Purchasing guide to first year students. First years could be
informed that Colby does not intend dorm room lighting to be sufficient, compact
fluorescent bulbs could be recommended. The availability of compact fluorescent light
bulbs and smaller energy star appliances in the Colby bookstore would be a positive start
to encourage environmentally responsible living.

2. Campus wide compact fluorescent bulb exchange sponsored in the beginning of
the fall. It would be environmentally and economically beneficial for Colby to sponsor a
compact fluorescent light bulb exchange campus wide next year. The exchange would be
most effective if coordinated at the beginning of the year to allow maximum payback
period for the bulbs within one school year. The Environmental Studies Club and other
interested students could coordinate the swap. Either a free compact fluorescent exchange
and or a discounted exchange would be beneficial. It is important to stress that more
energy would be saved and more students involved if the compact fluorescent bulbs were
provided free of charge.

The compact fluorescent bulb exchange conducted in offices was well received and
will save money for the college. A more extensive exchange for all faculty and staff
offices could be conducted in the fall as well. Compact fluorescent bulbs are likely to
remain in offices for their lifetime, which will increase the amount of energy and money
saved by the swap.

3. Green computing education in dorm rooms and with all first years. Despite the
existence of effective handouts, green computing education is still lacking at Colby. One
student in the open answer section of the survey suggested ITS offer to set incoming
students computers on the power down mode, and educate students about green
computing. Green computing information is available on the Colby green webpage (www.colby.edu/green) and the ITS webpage (http://www.colby.edu/info.tech/green/), but much of the campus is unaware of this resource. Green computing tips could be provided on each desk when students move in by Head Residents and emailed to all students in the beginning of the year. Setting up a power saving mode and practicing energy conscious computing behavior could become habits for more students, if they started the school year that way. It is important to reach them in the beginning before behavioral patterns are created.

4. **HR and PPD heat education after fall break.** Harvard and Bowdoin have shown positive results from peer environmental education. In the fall, Head Residents could inform students of how the heating is broken up into zones, and which student rooms have thermostats in each zone. Charts could be created for each dorm laying out the rooms, showing the zonation, and identifying thermostats so residents could discuss heating options. This will not always work but at least people will be more informed. This information along with the sheet PPD distributes on cold and hot rooms would explain heating more thoroughly to students. An opportune time for this teaching to occur would be after fall break. Students do not think of heating in their rooms until they are cold. The most effective time to reach them would be when they are concerned with the issue.

**Year Long Student and Administrative Action:**

1. **Pledge to turn off appliances during breaks from school.** Harvard’s campaign over Thanksgiving break to turn off all appliances could easily be replicated and save significant electricity. Colby could mandate to turn off all appliances, namely computers
and refrigerators, for fall break, thanksgiving break, and winter break. The dorm experiment indicated that when most students left for spring break, electricity use went down but not as far as possible. Education can be as simple as emails from HRs and signs in dorms. Lots of electricity is typically wasted each break. After the break, students could be educated about how much electricity they saved, because the data from this year’s electricity use can be the baseline for comparison.

The possibility of switching off electricity for all dorms could also be investigated. If the Physical Plant had the capability to turn off the electricity in each dorm, then students could be warned about this decision beforehand, and no electricity would be wasted during breaks.

2. Continued education about sustainable living in dorm rooms. After the model dorm room was created and the energy survey data analyzed, ample information on different appliances and how much electricity they use is now available. To raise awareness, a large table could be constructed informing students about electricity use by each appliance. The Energy Subcommittee could organize this appliance education. While this would not change the behavior of some, the knowledge it provides others could change some behavioral patterns.

3. PPD investigation of more individualized thermostats in all dorms on campus. Many students suggested in the open answer section of the energy use survey to set the thermostats so that heat could be turned down, but not up. The energy use survey uncovered serious heating issues. Many students called for individual thermostats. Bowdoin’s LEED certified dorms all have individual thermostats to ensure the least
amount of energy is wasted. Maybe it is too much of an economic endeavor to give all
dorms individual thermostats, but potentially a compromise could be investigated.

4. Make dorm energy competition results and dorm electricity metering available
online. Colby’s electricity metering is in the stage where it can support a dorm energy
competition. Bowdoin saved thousands of dollars over a month in their energy
competition. Dorm energy competitions save money and raise awareness. Professor
Tom Tietenberg has raised the idea of sharing the economic savings from energy
conservation with dorms that lower their energy use. This could be achieved through
working with PPD or the EAG. The availability of energy use data online would raise
consciousness about energy use and provide a positive incentive to use less energy. A
dorm energy use competition would do this in the short term. The competition would be
much more effective if results were updated online so students could access and view
them frequently. A dorm energy competition could provide a reason to make electricity
use data available online; similar to the system Oberlin College has working. Oberlin has
real time data, but the set up is the same. A dorm energy competition could provide a trial
run in electricity use data available online. Metered electricity data available on the web
is feasible for Colby in the future, and could have a strong positive impact on student
electricity use. Providing use data on the web is one way to connect students to their own
energy consumption patterns. It will also create a systematic storing of data and
encourage constant maintenance of meters. Web access to data is necessary regardless of
an energy competition. Eventually Colby should strive to make electricity use data
available on real time, like Oberlin. Oberlin demonstrated larger electricity reductions
with dorms that had access to real time data.
Long Term Collaborative Action:

1. **Purchase photovoltaic panels for roofs on campus.** Photovoltaic panels on campus are in the future. Colby PPD and administration have discussed the potential of photovoltaic panels. Although they are expensive, they would repay their cost eventually because they have a one time cost. They would also be a visible statement of Colby's campus sustainability. Even biomass and hydropower, parts of Colby's renewable energy package, now have their limitations to being labeled renewable. However, solar energy is renewable and would be a lasting investment for the campus.

2. **Sustainable dorm renovations.** LEED now certifies renovations as well as new construction. In the dorm renovations to come, Colby should work to come closer to meeting LEED certified renovations criteria, especially in terms of energy conservation. Certain issues such as better light placement and individual room monitors could be investigated and experimented with in the next round of renovations.

3. **Hire a sustainability coordinator.** A campus sustainability coordinator would work well at Colby and likely pay off his/her salary in energy and resource use reduction. Bowdoin, Brown, and Harvard have achieved great sustainable steps with their coordinators.

VIII. Conclusion

Energy use conservation is an important issue with practical solutions. Colleges have the resources, both in people and money, to make great headway in sustainability pursuits. This not only creates a model for all the members of the college community, but also creates a trend for other institutions and individuals to follow. Changes to
behavioral patterns can affect people for the rest of their lives. Practicing sound computer energy management practices and using compact fluorescent bulbs may have smaller impacts in the short term, but in the longer term they will lower emissions that are harmful to the earth's atmosphere and diminish the potential contribution to global warming. They also create a trend toward environmentally conscious living, which can bleed into other modes of life.

Energy conservation is also economically beneficial. It would help the college and students alike to conserve. Dorms pose an interesting problem since students are disconnected with the amount of energy use, but education in a multitude of forms can help lessen that divide. One plausible solution is to make dorm electricity metering available online, and to introduce the technology to the students through a dorm energy competition. Through this thesis work, an understanding of energy use habits and areas to conserve energy has been highlighted. Data collection is invaluable because of all the possibilities for future studies that availability of the data will create. The privilege in acting within the Colby framework is that this thesis is part of a movement. Its information and ideas will not remain within this written text; concerned parties may take action from this and will use the information for other unforeseen efforts as well.

The nature of this study has been rewarding and enriched by my being a college student on this campus. This is my context, and consequently I understand many avenues for energy conservation action innately. It has also deepened my understanding and appreciation of the college, both through revealing underlying processes and working with many different members of the college community, faculty, staff, administration and students. I hope that other Environmental Studies students as well as students in other
applicable majors continue the tradition of researching our own community through experiential action in which I have been privileged to have participated.

One potential area for growth is communication among departments. The gap between the PPD and administration and faculty is being lessened through diverse efforts. The EAG and Energy Subcommittee have contributed greatly to that dialogue and collaboration in efforts. Bowdoin, Brown, and Harvard have ongoing and successful collaboration with their PPD equivalents. The integration of student efforts and studies in campus sustainability efforts is such an invaluable resource. Oberlin is a shining example of this, as is Brown. Two avenues students can be involved is by employment or class and independent projects. Employment seems effective as long as the monetary resources are available. Student led efforts for campus sustainability through studies and class activities allows for greater analysis and support of this form of activism. It also creates training for jobs related to sustainability and environmental consulting.

Dorm energy conservation is an issue that has numerous solutions, but requires collaboration and planning to be effective. The baseline data and knowledge exist at Colby College to encourage further education and technological innovation to curb energy use. The recommendations of this thesis will be shared with PPD, the EAG, faculty, administration, trustees and students alike. It is my hope that these recommendations are not just ideas but also seedlings for change. The economic, social, and environmental benefits support these efforts; the time for implementation is now.
Acknowledgements

I would like to acknowledge and thank the individuals who generously contributed their, time, efforts and knowledge to my study.

The Environmental Advisory Group has taken many impressive steps toward campus sustainability. Their efforts and resources created an opportunity for my research. The Energy Subcommittee worked to educate on energy use issues and provided complimentary work to my thesis.

The Physical Plant Department was invaluable with their time, resources and expertise. John McCutcheon surveyed all the dorms personally with me. Dale DeBlois met with me on numerous occasions to provide information and coordinate the dorm energy experiment. Patricia Murphy is a member of the EAG and Energy Subcommittee; she also facilitated my thesis work with PPD. Tom Mayo met with me to explain and interpret metered electricity data.

Most importantly, my research would not have been possible without the help of my professors. Professor Dave Firmage provided crucial statistical analysis help with my energy use survey. Professor Tom Tietenberg read and edited my thesis extensively, and provided helpful commentary along the way.

Professor Russ Cole was my thesis advisor. He provided me with the initial inspiration to undertake this study. He spent countless hours helping me with different aspects of my study. His guidance made this work what it is, and I am incredibly grateful.

Without the help of all those listed below, this thesis would not have been possible. Thank you.

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Professor Tom Tietenberg  Thesis Reader, Environmental Studies Program, Colby College
Professor David Firmage  Environmental Studies Program, Colby College
Beth Kopp  Environmental Studies Program, Colby College
Dale DeBlois  
Environmental Program Manager, Physical Plant Department, Colby College

Pam Dudley  
Stockroom Manager, Physical Plant Department, Colby College

John McCutcheon  
Head Electrician, Physical Plant Department, Colby College

Patricia Murphy  
Director of Physical Plant Department, Colby College

Tom Mayo  
Heat and Vent Mechanic, Physical Plant Department, Colby College

Craig Shores  
Electrician, Physical Plant Department, Colby College

Ray Phillips  
Director of Information Technology Services

Members of Energy Subcommittee

Members of the Green House

Members of the Environmental Advisory Group
### Personal Communications

<table>
<thead>
<tr>
<th>Name</th>
<th>Position and Department</th>
</tr>
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<tbody>
<tr>
<td>William Adams</td>
<td>President, Colby College</td>
</tr>
<tr>
<td>Gordon Cheesman</td>
<td>Associate Director, Physical Plant Department, Colby College</td>
</tr>
<tr>
<td>Dale DeBlois</td>
<td>Environmental Program Manager, Physical Plant Department, Colby College</td>
</tr>
<tr>
<td>Pam Dudley</td>
<td>Stockroom Manager, Physical Plant Department, Colby College</td>
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</tr>
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<td>Director of Information Technology Services, Colby College</td>
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Appendix A. Energy Use Survey

Student Dorm Electricity Use

This survey is sponsored by the Environmental Studies Program and the Energy Subcommittee of the Environmental Advisory Group. Its intent is to determine patterns of electricity use in dorm rooms at Colby College. The results of the survey will be used to help develop strategies for working toward future energy efficiency in dorm rooms. Please take the time necessary to complete this survey, so that we will be better able to represent student opinion in decisions related to dorm energy conservation. Thank you in advance for your participation.

This survey is restricted to eligible students only. The request for your DCE login and password was so the system can identify you as an eligible student. However, from this point forward the survey submission will be confidential and it will be impossible to match an individual student with a specific survey response.

1. What is your class year?
   - 2009
   - 2008
   - 2007
   - 2006

2. What is your gender?
   - Female
   - Male

3. Do you live on campus?
   - Yes
   - No

4. If you live on campus, where do you live?
   - [pop down list of dorms]
   - Alford Apartments
   - Anthony
   - Averill
   - Coburn
   - Co-op
   - Dana
   - Drummond
   - East Quad
   - Foss
   - Goddard-Hodgkins
   - Grossman
   - Heights
   - Johnson
   - Leonard
   - Marriner
   - Mary Low
   - Mitchell
   - Perkins-Wilson
   - Pierce
   - Piper
   - Schupf
   - Sturtevant
   - Taylor
   - Treworgy
   - West Quad
   - Williams
   - Woodman
5. How many hours do you use dorm room lighting on a typical day during the school week?

<table>
<thead>
<tr>
<th>Hours</th>
<th></th>
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</thead>
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<tr>
<td>0-3 hours</td>
<td>13-15 hours</td>
</tr>
<tr>
<td>4-6 hours</td>
<td>16-18 hours</td>
</tr>
<tr>
<td>7-9 hours</td>
<td>19-21 hours</td>
</tr>
<tr>
<td>10-12 hours</td>
<td>22-24 hours</td>
</tr>
</tbody>
</table>

6. How many hours do you use dorm room lighting on a typical day during the weekend?

<table>
<thead>
<tr>
<th>Hours</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 hours</td>
<td>13-15 hours</td>
</tr>
<tr>
<td>4-6 hours</td>
<td>16-18 hours</td>
</tr>
<tr>
<td>7-9 hours</td>
<td>19-21 hours</td>
</tr>
<tr>
<td>10-12 hours</td>
<td>22-24 hours</td>
</tr>
</tbody>
</table>

7. Is the lighting that Colby has provided in your dorm room adequate for doing school work?

- Always
- Frequently
- Sometimes
- Rarely
- Never
- Comments Box

8. If you have a lamp in your dorm room, how often do you use that light exclusively rather than turning on the ceiling lights?

- Always
- Frequently
- Sometimes
- Rarely
- Never

9. If you do not have a lamp in your dorm room now but were given a lamp, how often do you think that you would use it and not use the ceiling lights?

- Always
- Frequently
- Sometimes
- Rarely
- Never

10. Would you participate in an exchange of the existing incandescent bulbs in your lamps for more energy efficient compact fluorescent bulbs, if the compact fluorescent bulbs were free?

- Yes
- No
11. How many incandescent bulbs (traditional bulb shape) are there in your dorm room?
   1 4
   2 5
   3 >5

12. Would you participate in an exchange of the existing incandescent bulbs in your lamps for more energy efficient compact fluorescent bulbs, if the compact fluorescent bulbs were offered at a discounted price (e.g., 50% reduction in cost)?
   Yes
   No

13. Do you turn off all of the lights when you leave your dorm room?
   Always
   Frequently
   Sometimes
   Rarely
   Never

14. Do you turn off all of the lights when you are the last one to leave a dorm lounge or other common space?
   Always
   Frequently
   Sometimes
   Rarely
   Never

15. Are you content with the heating in your room?
   Always
   Frequently
   Sometimes
   Rarely
   Never
   Comment Box

16. Would you like your room temperature to be on average
   Colder
   Warmer
   More responsive to varying ambient temperature
   What it is now

17. On the average day during the heating season, do you keep your window(s) open
   0-3 hours  13-15 hours  Always keep them closed
4-6 hours 16-18 hours
7-9 hours 19-21 hours
10-12 hours 22-24 hours

18. Are you aware of the factors that can influence your dorm room heating?
   Very Aware
   Moderately Aware
   Slightly Aware
   Not aware

19. Do you have a
   Refrigerator  Video game  Television  VCR  DVD  Computer
   Stereo  Extra lights  Hair Drier  Alarm Clock  Fish Tank  Microwave
   Computer Speakers  Hot Water Boiler  George Forman Grille
   Hair Straightener/Curling iron  Iron  Amp
   Fan  Humidifier  Space Heater  Toaster Oven
   Printer  Radio  Blender  Electric Coffeemaker
   Other electric device? [Text box]

20. Check off the five appliances you use most during the day
   List again

21. On the average day, what is the duration of use of each appliance listed below
   Appliance
   Television
   Video Game
   Computer Speaker
   Stereo
   VCR/DVD

22. How many power strips do you use in your dorm room?
   0
   1
   2
   3 or more

23. How many extension cords do you use in your dorm room?
   0-1
   2
   3
   4 or more

24. How often do you share your electric appliances with your roommate or neighbors
during a typical week?
   Always
25. How many hours on average do you leave your computer on [including sleep mode] during the day (24 hours)?
   - 0-3 hours
   - 4-6 hours
   - 7-9 hours
   - 10-12 hours
   - 13-15 hours
   - 16-18 hours
   - 19-21 hours
   - 22-24 hours

26. How many hours per day do you use your computer [have it perform activities, not just leave on]?
   - 0-3 hours
   - 4-6 hours
   - 7-9 hours
   - 10-12 hours
   - 13-15 hours
   - 16-18 hours
   - 19-21 hours
   - 22-24 hours

27. Do you leave your computer on over night to receive AOL Instant Messages?
   - Always
   - Frequently
   - Sometimes
   - Rarely
   - Never

28. Do you put your computer to sleep when it is not in use for more than a half an hour?
   - Always
   - Frequently
   - Sometimes
   - Rarely
   - Never

29. Do you turn your computer off when it is not in use for more than a half an hour?
   - Always
   - Frequently
   - Sometimes
   - Rarely
   - Never

30. Do you use a screen saver that is activated after a period of setting idle?
   - Yes
   - No
31. It is important for Colby students to act in ways that minimize their impact on the environment.
   Strongly agree
   Agree
   Neither agree or disagree
   Disagree
   Strongly disagree

32. It is important for students to assist Colby in reducing energy costs.
   Strongly agree
   Agree
   Neither agree or disagree
   Disagree
   Strongly disagree

33. In comparison to other Colby students, how much energy do you think that you use in your dorm room?
   Much less
   A little less
   About the same
   A little more
   Much more

34. In your opinion, what is the most electricity efficient action you take?
   Open answer

35. What is the least electricity efficient action that you practice?
   Open answer

36. In your opinion, what do you think could be done to make dorm rooms more electricity efficient?
   Open answer

37. In your opinion, what do you think could be done to make dorm rooms more heating efficient?
   Open answer
Appendix B. Dorm Energy Education Poster One

Think About it

Are Your Lights and Appliances Turned Off??
Appendix C. Dorm Energy Education Poster Two

**Computer Energy Use**

Computers have fast become one of the largest consumers of electricity on college campuses across the country. The EPA has estimated that using the ‘sleep mode’ on equipped computers nationwide would reduce their energy use by 60% to 70%. This could save enough electricity each year to power Vermont, New Hampshire and Maine, cut electric bills by $2 billion, and reduce CO2 emissions by the equivalent of 5 million cars. If the Colby community turned its printers and computers off overnight and on weekends, over $42,000 would be saved annually.

**What Can You Do?**

1. Turn off your computer! A modest amount of turning on and off will not harm the equipment. Leaving it on all night and all weekend wastes energy. If the computer will be idle for more than 16 minutes, it would consume less energy to turn it off and on again - this does not damage the computer or shorten its lifespan.
2. Group your computer activities and try to do them during one or two parts of the day, leaving the computer off at other times. Break the habit of switching the machine on every morning.
3. Turn the monitor off. Screen savers consume as much electricity as the monitor does when in active use.
4. Set your computer to ‘sleep’ or ‘stand by’ when not in use for a certain period of time. Consult your control panel for setting options.
5. Don’t turn your printer on until you are ready to print. Printers consume energy even when idling.
Appendix D. Dorm Energy Education Poster Three

The Cold/Hot Dorm Room Breakdown

Facts:
- The college turns on heat when the outside temperature drops below 55 degrees on a regular basis.
- The heat in residence halls is set between 65 and 70 degrees.
- The heat in residence halls is not done on a room by room basis. It operates on two or more zones depending on factors such as relationship to the sun and location of the room within the building. Outside air temperature, room size, number of windows, number of exterior walls, number of people and amount and placement of furniture in a room all impact the temperature.

What should I do if my room is too hot?
First, check on a couple causes:
- Is the outside temperature much warmer today than yesterday? The heating system in a large building can be slower to adjust to fluctuating outside temperatures. This can be a particular problem in the fall and spring when the daily highs can vary by 20 or 30 degrees.
- Is there a window or door open elsewhere in the building that could be activating the heat?

If that's not the cause please do the following:
1. DO NOT simply open the window. It wastes energy, it will not solve the problem, and it could actually make it worse.
2. Call the PPD Hot/Cold line at X3895 and leave all your basic information.

What should I do if my room is too cold?
First, check on a couple causes:
- Make sure that the radiator or baseboard heat is not obstructed. If furniture is placed directly in front of the heat, pull it away to allow the air to circulate.
- Check to make sure that there are no heat producing items, such as a refrigerator, computer, or lamp placed in front of a thermostat or sensor. This would give a false reading of warm temperature to the thermostat/sensor.
- Check to make sure that there are no windows open. When closed, windows must be securely latched. If you have a storm window, ensure it is down and locked as well.
- Dress for the season! Put on a sweater and some wool socks. We are in Maine.

If these do not seem to be the cause, please do the following: Call the PPD Cold/hot line at X3895
Appendix E. Dorm Energy Education Poster Four

GREEN PURCHASING AND LIVING GUIDE

SPONSORED BY THE DEAN OF STUDENTS OFFICE AND THE ENVIRONMENTAL ADVISORY GROUP

The Environmental Advisory Group was formed by President Adams to advise him on the environmental initiatives of the College. Part of its mission is to promote environmental stewardship among Colby community members through awareness programs. The lifestyle decisions of students affect Colby’s environmental footprint; the total energy and resources we consume.

Please view the Green Colby website www.colby.edu/eag/ for more information on Colby's environmental accomplishments and ways students can make a difference.

Sustainable Living

RECYCLING
Colby has an active recycling program. Paper, cans, and bottles can be recycled in every dorm and college building. To maximize this program, present your waste between trash and compostable/recyclables. At the beginning of each year, Colby holds a RESCUE - Recycling Everything Saves Colby’s Unwanted Excess - sale, where used dorm supplies, appliances, and furniture are sold. At the end of each year, students can avoid the waste stream by giving their unwanted clothes, furniture, and dorm supplies to Colby RESCUE.

LAUNDRY
Colby recently installed Energy Star rated front loading washing machines and dryers. These new machines are projected to save 3 million gallons of water and $10,000 in energy costs annually. They also have a larger load capacity, so you can do two loads for every three loads done using a standard washer and dryer, while using 75% less detergent per load (only two tablespoons per load).

DINING SERVICES
Green Colby has been collaborating with Dining Services to purchase of sustainably harvested seafood at Colby. Dining Services also compost pre- and post-consumer waste at all dining halls. Personal actions like minimizing food waste and avoiding paper cups and plates support the sustainability efforts of Dining Services. Look for other greening initiatives in the dining halls during the year.

Sustainable Computer Tips

Computers and printers are some of the largest consumers in energy and water use at a college. But it is not just the number of computers that is driving energy consumption upward, but the way computers are being used.

1. Set your computer to "sleep" or "standby" after several minutes of non-use.
2. Screen savers generally consume more energy than sleep mode, monitor shutdown, or shutdown, and are considered unnecessary for use in new computers.
3. Turn off your monitors. Monitors can consume two or three times as much electricity as the hard drive.
4. Turn off your computer at night. Turning a computer off and on saves more energy than leaving it idle for 15 minutes. This does not damage the computer or shorten its lifespan.
5. Break the habit of switching the computer on every morning unless you plan to use it.
6. Follow recommended energy saving instructions provided with your printer manual.
7. See www.colby.edu/uax/info/green/ for more tips.

Top 10 Sustainability Tips

Just as important as green purchasing is minimizing your resource use and waste streams. Below is a list of some of the things you can do to conserve resources and minimize waste.

1. Buy goods with some recycled content; this creates a market for recycled material.
2. Consider the lifetime of a product. Try to reduce your use of disposable items (cups, plates, coffee cups) and items with excessive packaging.
3. Edit documents on the computer screen as much as possible to avoid printing multiple drafts.
4. Do not print unless you have to. Then, print on both sides of the paper.
5. Minimize water use: Don't fill a pot with water until you need it.
6. Don't wash dishes constantly when brushing your teeth or shaving; and limit your shower time.
7. Close storm windows and windows you see open during cool months.
8. Turn off lights that are not in use.
9. Find new uses for old things. For example, recycle grocery bags as trash bags.
10. Give unwanted appliances, clothing, and furniture to Colby RESCUE at the end of the year so that they can be recycled and remain out of the waste stream.

"Treat the Earth well. It was not given to you by your parents. It was borrowed from your children."

Korean Proverb

"Men did not weave the web of life, he is a strand on it.
Whatever he does to the web he does to himself."

Chief Seattle
Energy Star®:

Appliances make a dorm room feel comfortable, but there are many purchasing choices that may also reduce your impact on the environment. Green products are more efficient and save money in energy costs.

Energy Star is the Environmental Protection Agency’s program for labeling products with superior energy efficiency. When you purchase an Energy Star product, you reaffirm the power of the individual in making a difference and that the environmental choice provides energy savings without compromising quality or comfort. In the last decade, Americans have purchased over one billion Energy Star rated products.

The following Energy Star rated products are often purchased for dorm rooms: Refrigerators, Printers, Scanners, TVs, VCRs, DVD Players, Stereos, Phones, Desk Lamps, Floor Lamps, Light bulbs, and Compact Refrigerators.

Learn more about the Energy Star program and where to purchase Energy Star rated products in your area at www.energystar.gov

Green Purchasing

THE ENVIRONMENTAL ADVISORY GROUP ASKS THAT YOU PLAN AHEAD FOR YOUR DORM ROOM AND CONSIDER THE POTENTIAL ENVIRONMENTAL IMPACTS OF EACH PURCHASE YOU MAKE. TALK WITH YOUR ROOMMATES ABOUT PURCHASING COMMUNAL APPLIANCES, AND CONSIDER WHAT APPLIANCES AND SUPPLIES ARE ALREADY AVAILABLE FOR STUDENTS TO USE IN THEIR DORM AND ON CAMPUS.

Computing

Notebook computers use 80% less energy than desktops. Flat panel monitors use less energy and increase available desk space. Energy Star rated computers, monitors, and printers will automatically enter a low power mode after a period of inactivity.

Printing

Wait until you get to campus before purchasing a personal printer to use what resources are available for printing documents. Although Colby provides free access to printers, please print only when necessary. Centralized printing can cut down on energy use. You can use your Zip Disk, CD-ROM, or e-mail account to transfer your documents to a campus computer for printing.

If you choose to purchase a printer, you can recycle ink and laser toner cartridges on campus. Also, purchase remanufactured (not recharged) toner cartridges.

Entertainment

TVs use more energy than any other household electronic equipment, even when they are turned on because we never are on them. Watching TV in your residence hall lounge saves energy and is a great way to meet your neighbors.

Energy Star audio equipment can use one-tenth the energy of standard models. Many students use their computers to play music, which cuts down on buying extra electronics AND saves energy.

Bath and Laundry

Biodegradable and non-toxic laundry soaps can be bought or made by microorganisms, reduce nutrient loading, and are non-toxic to aquatic species. Instead of using the dryer, consider drying your clothes on a drying rack.

Lighting

Compact Fluorescent Light bulbs (CFL) use 75-85% less energy than incandescent light bulbs, last 10 times longer, and provide high-quality light.

To use the most efficient task lighting possible, replace incandescent bulbs with CFL bulbs or purchase lamps that use fluorescent tubes or High Intensity Discharge (HID) bulbs.

Phones

Cordless phones use energy continuously. Cordless phones with an Energy Star rating use about one-third of the energy of standard models. If possible, purchase a phone with a cord.

Furniture and Carpeting

Purchase second-hand furniture and other supplies (shelves, lamps, storage containers) at thrift stores and at the Colby RESCUE sale before classes begin in the fall. Scrap carpeting (leftover pieces of commercial carpeting) is economical and comes in many sizes.

Refrigerators

Standard compact refrigerators purchased for dorm rooms may use almost as much energy as full-sized models. Energy Star rated models use approximately 25% less energy. Sharing a compact refrigerator with roommates or hall mates is an excellent way to save energy.

Class Supplies

Most class supplies are available with recycled or sustainably made materials. Try to purchase supplies that are durable and reusable. Purchase non-chlorine and non-deinked paper with a high recycled content. Use scrap paper for notes (a binder can keep your notes organized). Purchase used books, share books with friends and classmates, or check books out from Colby Libraries.
Appendix F. Energy Star Calculations for Compact Fluorescent Light Bulb Free Exchange

Life Cycle Cost Estimate for 1625 ENERGY STAR Qualified Compact Fluorescent Lamp(s)

This energy savings calculator was developed by the U.S. EPA and U.S. DOE and is provided for estimating purposes only. Actual energy savings may vary based on use and other factors.

Enter your own values in the gray boxes or use our default values.

<table>
<thead>
<tr>
<th></th>
<th>ENERGY STAR Qualified Unit</th>
<th>Conventional Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity rate ($/kWh)</td>
<td>$ 0.149</td>
<td></td>
</tr>
<tr>
<td>Hours used per day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial cost per unit (estimated retail price)</td>
<td>$10.00</td>
<td>$1.00</td>
</tr>
<tr>
<td>Wattage (watts)</td>
<td>14</td>
<td>68</td>
</tr>
<tr>
<td>Lifetime (hours)</td>
<td>12,000</td>
<td>750</td>
</tr>
</tbody>
</table>

Annual and Life Cycle Costs and Savings for 1625 CFLs

<table>
<thead>
<tr>
<th></th>
<th>1625 ENERGY STAR Qualified Unit</th>
<th>1625 Conventional Unit</th>
<th>Savings with ENERGY STAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Operating Costs*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy cost</td>
<td>$7,424</td>
<td>$34,057</td>
<td>$36,484</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>0</td>
<td>$11,085</td>
<td>$13,065</td>
</tr>
<tr>
<td>Total</td>
<td>$7,424</td>
<td>$47,142</td>
<td>$39,718</td>
</tr>
<tr>
<td>Life Cycle Costs*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating cost (energy and maintenance)</td>
<td>$49,981</td>
<td>$317,163</td>
<td></td>
</tr>
<tr>
<td>Purchase price for 1625 unit(s)</td>
<td>$1,625.00</td>
<td>$1,625.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>Total</td>
<td>$46,371</td>
<td>$316,888</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

Simple payback of initial additional cost (years)*: 0.4

Summary of Benefits for 1625 CFLs

<table>
<thead>
<tr>
<th></th>
<th>$14,855</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life cycle savings</td>
<td></td>
</tr>
<tr>
<td>Net life cycle savings (life cycle savings - additional cost)</td>
<td></td>
</tr>
<tr>
<td>Simple payback of additional cost (years)</td>
<td>0.4</td>
</tr>
<tr>
<td>Life cycle energy saved (kWh)</td>
<td></td>
</tr>
<tr>
<td>Life cycle air pollution reduction (lb of CO₂)</td>
<td></td>
</tr>
<tr>
<td>Air pollution reduction equivalent (number of cars removed from the road for a year)</td>
<td>205.71</td>
</tr>
<tr>
<td>Air pollution reduction equivalent (area of forest)</td>
<td>324.39</td>
</tr>
<tr>
<td>Savings as a percent of retail price</td>
<td>135298</td>
</tr>
</tbody>
</table>
Appendix G. Energy Star Calculations for Compact Fluorescent Light Bulb Discounted Exchange

### Life Cycle Cost Estimate for 1125 ENERGY STAR Qualified Compact Fluorescent Lamp(s)

This energy savings calculator was developed by the U.S. EPA and U.S. DOE and is provided for estimating purposes only. Actual energy savings may vary based on use and other factors.

#### Enter your own values in the gray boxes or use our default values.

<table>
<thead>
<tr>
<th>Number of units</th>
<th>1125</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity rate ($/kWh)</td>
<td>$0.140</td>
</tr>
<tr>
<td>Hours used per day</td>
<td>12,000</td>
</tr>
</tbody>
</table>

#### Conventional Unit

<table>
<thead>
<tr>
<th>initial cost per unit (estimated retail price)</th>
<th>$7,100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage (watts)</td>
<td>65</td>
</tr>
<tr>
<td>Lifetime (hours)</td>
<td>7,500</td>
</tr>
</tbody>
</table>

### Annual and Life Cycle Costs and Savings for 1125 CFLs

#### Annual Operating Costs

<table>
<thead>
<tr>
<th>1125 ENERGY STAR Qualified Units</th>
<th>1125 Conventional Units</th>
<th>Savings with ENERGY STAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy cost</td>
<td>$4,283</td>
<td>$20,802</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>$0</td>
<td>12,461</td>
</tr>
<tr>
<td>Total</td>
<td>$4,283</td>
<td>$28,263</td>
</tr>
</tbody>
</table>

#### Life Cycle Costs

| Operating cost (energy and maintenance) | $28,835 | $191,633 | $162,798 |
| Purchase price for 1125 units(s) | $40,085 | $1,125,000 | $1,123,915 |
| Total | $68,920 | $1,125,000 | $1,123,915 |

Simple payback of initial additional cost (years) = 0.4

#### Summary of Benefits for 1125 CFLs

| Initial cost difference | $10,125 |
| Life cycle savings | $114,786 |
| Air pollution reduction (lbs of CO2) | 27,500 |
| Air pollution reduction equivalence (number of cars removed from the road for a year) | 190,85 |
| Life cycle energysaved (kWh) | 114,786 |
| Life cycle energy saved (kWh) | 27,500 |
| Air pollution reduction equivalence (number of cars removed from the road for a year) | 190,85 |
| Savings as a percent of retail price | 132.96% |
Appendix H. Compact Fluorescent Light Bulb Exchange Calculations

Free Compact Fluorescent Light Bulb Exchange:
Survey indicated 92% of students (1821 on campus) would participate in free exchange.
1625 students use each light bulb for 6 hours day (see Appendix F)
Energy cost for 8 months of using compact fluorescent bulbs:
7,424 (annual cost)/12 = $619 (energy use per month) x 8 (months of use during school year) = $4952

Energy cost for 8 months of using incandescent bulbs:
$36,057 (annual cost)/12 = $3,005 (energy use per month) x 8 (months of use during school year) = $24,040

Total cost difference:
Energy and purchasing costs for compact fluorescent bulbs:
$4,952 + 1625 x $10 bulb cost = $21,202

$24,040 - $21,202= $2,838 saved by free compact fluorescent bulb exchange

50% Discount Compact Fluorescent Light Bulb Exchange:
Survey indicated 62% of students (1821 on campus) would participate in discounted exchange.
1125 students use each light bulb for 6 hours a day (see Appendix G)
Energy cost for 8 months of using compact fluorescent bulbs:
5,139 (annual cost)/12 = $428 (energy use per month) x 8 (months of use during school year) = $3426

Energy cost for 8 months of using incandescent bulbs:
$32,305 (annual cost)/12 = $2,692 (energy use per month) x 8 (months of use during school year) = $21,537

Total cost difference:
Energy and purchasing costs for compact fluorescent bulbs at 50%:
$3426 + 1125 x ($5) = $9051

$21,537 - $9051 = $12,486 saved by a discounted (50%) compact fluorescent bulb exchange
Appendix I. Ray Phillips 2002 Computer Electricity Consumption Calculations

Computer Electricity Consumption (Watts):

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop</td>
<td>550</td>
<td>25</td>
</tr>
<tr>
<td>iMac</td>
<td>120</td>
<td>35</td>
</tr>
<tr>
<td>Notebook</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td>Printer</td>
<td>500</td>
<td>20</td>
</tr>
<tr>
<td>17&quot; CRT</td>
<td>125</td>
<td>20 CRT</td>
</tr>
<tr>
<td>15&quot; LCD</td>
<td>30</td>
<td>5 LCD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRT vs. LCD</th>
<th>daily kWh</th>
<th>Annual kWh</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRT</td>
<td>610</td>
<td>161.04</td>
<td>$14.49</td>
</tr>
<tr>
<td>LCD</td>
<td>147.5</td>
<td>38.94</td>
<td>$3.50</td>
</tr>
</tbody>
</table>

Daily Usage Pattern (from Energy Star cited research):

<table>
<thead>
<tr>
<th></th>
<th>Sleep</th>
<th>Mode</th>
<th>Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>ON</td>
<td>Off</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5.5</td>
<td>14.5</td>
</tr>
</tbody>
</table>

Daily consumption (kWh):

- Continuous use - screen saver, on 24 hours a day (Computer)
  - 13.20 kWh
- Screen saver use and turn off computer overnight (Computer)
  - 5.23 kWh
- 2.70 kWh Sleep mode but always on (Computer)
- 2.34 kWh Sleep mode and turned off over night (Computer)
- Continuous on, sleep when not in use
  - 2.40 kWh (Printer)
- 2.11 kWh Turn off overnight (Printer)

Screen Saver = Energy Waster (and It Has No Benefit for the Screen)

- **$433.62** Screen Saver running
- **$69.61** Screen Saver running
- **$124.15** Saver running
- **$55.54** Saver running

Annual cost of using a computer that is turned off evenings and weekends with Screen

- **$14.07** 20%
- **$42,201** Savings for 3000 computers

Annual electricity cost of using an iMac (turned off evenings and weekends/holidays)

- **$15.98**

Annual cost savings in using an iMac instead of standard desktop computer:

- **$39.56**
Appendix J. Recalculation of Computer Electricity Consumption Based on Phillips Data from 2002 and New Energy Star Requirements

### Computer Electricity Consumption (Watts):

<table>
<thead>
<tr>
<th>Normal</th>
<th>Sleep</th>
<th>LCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated G5</td>
<td>185</td>
<td>16</td>
</tr>
<tr>
<td>PowerMac</td>
<td>131</td>
<td>10</td>
</tr>
<tr>
<td>iMac</td>
<td>55</td>
<td>35</td>
</tr>
<tr>
<td>CPU</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>17&quot; CRT</td>
<td>57</td>
<td>3</td>
</tr>
<tr>
<td>17&quot; LCD</td>
<td>73</td>
<td>3</td>
</tr>
<tr>
<td>Flat panel</td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Normal</th>
<th>Sleep</th>
<th>Ready</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inkjet printer</td>
<td>86</td>
<td>10</td>
</tr>
<tr>
<td>Laser printer</td>
<td>108</td>
<td>20</td>
</tr>
</tbody>
</table>

#### Daily consumption (kWh):

- **3.14** Continuous use - screen saver, on 24 hours a day (Computer)
- **1.36** Screen saver use and turn off computer overnight (Computer)
- **0.72** Sleep mode but always on (Computer)
- **0.70** Sleep mode and turned off over night (Computer)
- **0.83** Continuous on, sleep when not in use (Printer)
- **0.54** Turn off overnight (Printer)

#### Daily consumption (kWh):

- **1.08** Continuous use - screen saver, on 24 hours a day (Notebook)
- **0.46** Screen saver use and turn off computer overnight (Notebook)
- **0.24** Sleep mode but always on (Notebook)
- **0.23** Sleep mode and turned off over night (Notebook)
- **0.83** Continuous on, sleep when not in use (Printer)
- **0.54** Turn off overnight (Printer)

### Screen Saver = Energy Waster (and It Has No Benefit for the Screen)

- **$170.99** Annual cost of using a computer that is turned on 24 hours/day, 7 days/week with Screen Saver
- **$39.37** Annual cost of using a computer that is turned on 24 hours/day, 7 days/week with NO Screen Saver
- **$52.23** Annual cost of using a computer that is turned off evenings and weekends/holidays with Screen Saver
- **$26.74** Annual cost of using a computer that is turned off evenings and weekends/holidays with NO Screen Saver

#### Amount saved by turning an energy saving computer or printer off overnight and weekends/holidays

- **$4.97** 12%

#### Savings for 3000 computers

- **$14,918**

#### Annual electricity cost of using an iMac (turned off evenings and weekends/holidays)

- **$17.46**

#### Annual cost savings in using an iMac instead of standard desktop computer:

- **$9.28**