AC 2012-4794: INCREASING STUDENT INVOLVEMENT IN A SUSTAINABILITY COURSE

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Increasing Student Involvement in a Sustainability Course

Abstract

Student projects that have been included as part of an engineering course for the past two years are described in this paper. It is a new course, which is an elective in the engineering and technology programs, titled "Energy Systems and Sustainable Design." The course includes material on the conversion of all forms of energy to electricity, as well as the sustainable design of buildings.

For the energy systems portion of the course the lecture material covers the various experimental and existing technologies. Reading assignments from scholarly or trade journals are assigned that relate to the topics and provide an engineering perspective to the (sometimes controversial) topics of electrical power generation. To conclude the energy portion of the course, the students are asked to write a report on an energy conversion technology of their choice.

The lectures for the sustainable design portion of the course are based around the LEED principles (Leadership in Energy and Environmental Design) for building design and construction. A test based on the LEED certification exam is given, and the students should be able to pass the national US Green Building Council exam which is the first step for professional certification as a LEED-AP.

The conclusion of the course is a final project that has involved both the energy usage and sustainability aspects of buildings on campus. In this way, the students need to synthesize the two portions of the course to develop the final project, and they are also being involved in energy-saving practices at the local campus community.

The paper discusses the use of projects in the course, especially the emphasis on the local energy issues that were brought out in the project. The overall intent of the course, to increase student awareness of energy and sustainability issues, is also discussed with regard to the project structure.

Introduction

Energy and sustainability are topics that have captured the imagination and concern of the popular culture. However, in spite of all of the popular interest, it falls to engineers to affect workable solutions that will have the desired results for society at large. As such, it is necessary that engineering students are exposed to the current practices in energy conversion and sustainability practices. Several courses have been described in the literature with a similar intent, including a freshman/sophomore course combination at Baylor University[1], which in a four semester sequence introduces the students to a wide variety of topics on energy and is also taught from an interdisciplinary perspective of electrical and mechanical engineering. The emphasis of this course is heavily on the engaged learning, whereby students are expected to be involved and conclude with a research project. Another course at the University of New York, Oswego[2] has incorporated energy topics into an introductory Physics course. The paper discusses a concept survey (a popular practice in the physics teaching community) which revealed that the students were aware of energy topics but were unable to relate the issues to active things that

they can do. There were also speakers who were invited to talk on different issues. A course taught at Penn State - Harrisburg[3] as part of the required Electrical Engineering curriculum emphasizes conversion of electricity and includes simulation techniques. This course is taught as an upper level course, requiring calculus and AC/DC Circuits, and includes a semester project that the students research and write a report in teams.

Several different courses[4,5,6] have been discussed that emphasize alternative energy to the apparent exclusion of traditional forms of electrical power generation. This introduces the alternative technologies which are lagging in adoption compared to the fossil fuels. Finally, courses have been developed from engineering programs that are aimed at other audiences, including high school teachers[7] and students at Tribal Colleges[8]. These and similar efforts show that the engineering education community takes seriously its leadership role in making a difference in energy efforts.

The present paper discusses a course that was designed to address the energy and sustainability questions on both fronts, first with regard to generation of electricity and then with the design of sustainable buildings, which are among the largest consumers of electricity. The LEED (Leadership in Energy and Environmental Design) criteria have emerged as the contemporary guidelines for sustainable design, which is why the students are introduced to these to represent the sustainable design component. The culmination of the course has been sustainability projects that the students complete in groups that relate to some aspect of buildings on campus.

Elements of previously discussed courses, such as the research projects and the interdisciplinary nature of the course have been incorporated into this course. The research project on an energy systems topic of the students' choosing allows them to expand on their own interests and has sometimes turned up topics that are novel to the instructors. The sustainability project being based on campus buildings gives the students reason to investigate topics that they can have some ownership in, namely buildings that they spend a lot of time in. The course has been a popular one based on student enrollment and feedback, and it is hoped that by describing the techniques used, other instructors can gain insight for their own courses.

Course Overview

This course is team-taught by the two authors of this paper. The first author is a Mechanical Engineer and teaches in the thermofluid areas with specialization in refrigeration cycles and refrigerant flows. The second author is a Civil Engineer, teaching in the construction areas and is a LEED-AP. The engineering program within which the course is offered is a BSE program, with emphases in Civil, Electrical, Industrial, Mechanical and Mechatronics. By using an interdisciplinary approach to the course, the course can serve a wider subset of the students in the program and demonstrate that the energy issues facing society are not limited to a single engineering discipline.

The course was divided into two parts, an Energy Systems part and a Sustainable Design part, roughly half of the semester each. In the Energy Systems part of the course, which came first, the students were introduced to various methods of energy conversion that lead to electrical power. The students were given relevant articles from trade magazines and the open literature that related to different topics which they were required to write short response papers to and

several class discussions about the articles. A research project on some sort of energy systems topic concluded this portion of the course, with a written report and short presentations by the students. The Sustainable Design part of the course started off with lectures on the LEED Green Professional criteria, and an exam was given using sample problems from the LEED exam. The Sustainability Project was a group project that investigated sustainability issues regarding different campus buildings. Final reports and group presentations were required in lieu of a final exam.

The course was intentionally taught without requiring Physics or Thermodynamics as prerequisites, so that it would be accessible to students who had not taken these courses. The student body was primarily freshmen and sophomores. Most of the students who were in the course were quite interested in energy topics, and some had strong opinions about the politically-charged aspects of energy production. However, it was the goal of the course to present the material in an objective, scientifically based manner to eliminate political bias and to enable students to see through the various biases that are often widespread.

Energy Systems

The focus of the Energy Systems portion of the course was on electricity and electrical power generation. It is desired at some point to include energy involved in transportation, however, there has never been enough time to include that topic in the schedule of lectures. With regard to electrical power, the classifications are always made with regard to energy conversion rather than "alternative" vs. "traditional" energy. The topics start with a quick overview of the conservation of energy. Conversion of chemical energy to electricity was the first topic, which covers photovoltaic, fuel cells, and batteries. Then, electromagnetism and how rotational power can be converted into electrical power by moving magnets through a magnetic field was addressed, which set up the concept of converting rotational energy to electricity. The generation of rotational energy provided the framework of the remainder of the topics, including hydroelectric, wind, and tidal, which directly generate rotational energy using a variety of physics, but also steam turbines, which produce rotational energy by means of thermal energy. The production of thermal energy brought in the topics of combustion of hydrocarbons and biomass (which is really a chemical energy conversion), as well as geothermal sources and nuclear reactions: both fission and fusion. Since any energy systems discussion should include pollution to be topically relevant, hydrocarbon emissions were addressed within the appropriate sections of the lecture within a chemical framework. In addition, photo tours of a local power plant and of a gas turbine engine were included as part of the lecture.

Part of the course involved reading of current articles and writing short response papers. Some of the articles were taken from the ASME magazine *Mechanical Engineering*. In addition, class discussions were held on several of the readings, to get the students to articulate the ideas that they had on the readings with their colleagues. These class discussions were structured around a series of questions that were developed to go with the articles to provoke engagement with the article. The intent of these sessions was to encourage students to be alert when engineering topics pass across the popular media, and to apply engineering reasoning to things that they read.

The Energy Systems Project was the conclusion of this portion of the course. The students were free to pick any topic pertaining to energy systems and write a research paper on the topic. Part

of the paper was that it had to include some sort of engineering analysis, which was some sort of quantitative calculation related to the subject of the report. The intent of this was to make the project go beyond a simple term paper, and to give it an engineering twist. The engineering analysis portion of the assignment was misunderstood by many of the students, and The students were given 5-10 minutes to present their topics to the whole class and a written report was turned in at the conclusion of the Energy Systems portion of the course.

Sustainable Building Construction

At the conclusion of the Energy Systems portion of the course, the focus is shifted to a block of instruction dedicated to sustainable building construction. Much of the material in this portion of the course is taken for the US Green Building Council's (USGBC) materials regarding Leadership in Energy and Environmental Design (LEED). The instructor for this portion of the course is a LEED Accredited Professional for Building Design and Construction (LEED AP BD+C) who has worked in the construction industry. The course is taught in such a way that students are prepared to take the initial qualifying examination for LEED accreditation, the LEED Green Associate exam.

The students are given lectures and exercises on the five major categories of LEED, sustainable sites, water efficiency, energy and the atmosphere, materials and resources, and indoor environmental quality. Since the focus of the course is energy, extra time is allotted for discussion of building energy efficiency. Guest speakers from the HVAC contractor for the building were invited to lecture the class. After conclusion of the lectures, the building itself was used as a large laboratory to reinforce many of the LEED design principles. The building itself was completed in 2010. Although it is not a LEED certified building, it was originally intended to be and many of the LEED design principles are readily evident. Of particular note, the HVAC performance of the building can be monitored via a software installation in one of our engineering laboratories.

The LEED block of instruction concludes with a computer based examination intended to prepare the students for the types of questions and pacing that they will experience on the LEED Green Associate examination. After conclusion of the LEED block of instruction, students are ready to jump into their sustainability projects.

Sustainability Projects

Each semester, a different set of group projects were assigned to conclude the Sustainability portion of the course. The first year that the class ran, both class projects were devoted to investigating and preparing the submittals for utility rebates that were available from the local power company as a result of various sustainability practices incorporated into the buildings. One building was the Business and Engineering Center, which had just been completed at the end of the previous summer, and the other building was the University Center Expansion, which was an addition to the student union building that was under construction that semester. The class was divided into two groups and each group took one building. The students first identified the qualifying technologies which required them to interact with the utility representative. Finally, they used blueprints and visited the machine rooms of the buildings to confirm all the installations. Unfortunately, as part of their work, the students discovered that the University is

categorized in a billing rate that does not qualify for the rebates. However, they completed the exercise as if it were a standard commercial construction that would qualify. It was discovered that the sustainability practices implemented into both buildings would have resulted in the maximum rebate allowable.

The second year of the course, two different projects were selected. The first project involved designing a way to attach electrical capture devices on to the exercise equipment at the campus fitness center. Different types of commercially available technology were investigated and the students communicated with the manufacturers to provide an approximate quote for the installed equipment. The students analyzed usage data for how many people and for how long people used different machines, and also conducted experiments on how much power could be produced by each of the machines. They communicated with a company who installs this equipment to get quotes and developed an economic estimate for installing energy harvesting equipment on different exercise machines. Based on their work, it was determined that the only real candidates for energy harvesting systems were 15 of the elliptical machines, since they were used approximately 344 hours out of the month. Even so, the simple payback period without any sort of subsidy was calculated to be just over 17 years for installing the energy harvesting systems on these machines.

The second project for the class was an audit on the Business and Engineering Center to investigate its energy usage over its first year of operation. This audit included: an analysis of the thermal design load from the blueprints; measurement of plug loads throughout the building from vending machines, projectors, television monitors and lab computers; measurement of the CO2 levels in classrooms, student study spaces, and offices; measurement of light levels in the classrooms at various times throughout the day; infrared photographs of the building thermal envelope; and measurements of the indoor temperature gradients throughout the different levels of the building. Each group of students did a different part of the project, and presented their findings in the final reports and presentations.

The plug load analysis involved using a watt meter to measure the various devices that were installed in the building. To list a few of the things that fit into this category, the seven soda machines in the building (without the refrigeration cycle running) consumed 111 W each, while the two snack machines only consumed 45 W each. Throughout the building in offices, classroom and labs, there were 546 computers, each consuming approximately 180 W. There are 35 TVs in the building, which each consume 81 W. Taken all together, the miscellaneous plug loads totaled more than 100 kW. This is a significant additional load.

The measurements of light levels and temperatures both came out well. The building uses a lot of natural lighting, and the light levels measured at a number of different locations during the day were more than sufficient for regular lighting levels. In the evening, or even on overcast days, some of the lighting levels were close to the recommended levels for student use. The building has an open four-story atrium, but no temperature stratification was detected from the bottom to the top of this open space, indicating that the HVAC system was operating as designed.

One of the thermal images that were taken of the building is shown in Figure 1. The image is looking up toward the skylight at the top of the atrium. Cold regions can be seen at the window

frames, but vertical cold lines can also be seen in the walls. These are the locations of the metal studs that represent a lower insulation to the cold outdoors.

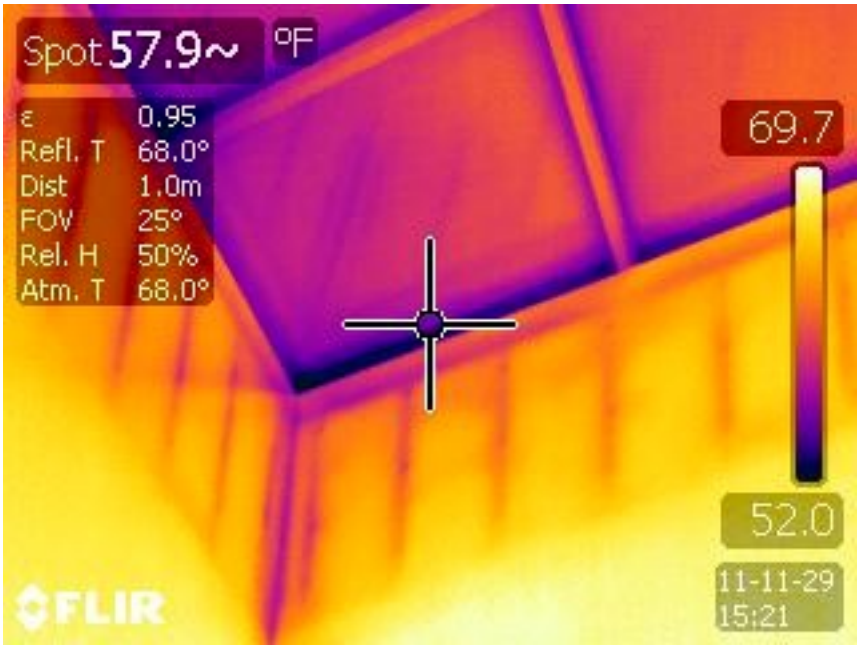

Figure 1: Thermal image of the interior wall and skylight of the atrium of the Business and Engineering Center. The cold studs in the walls are clearly visible in the image.

Conclusions, Path Forward

A course in energy systems and sustainable design has been described. The course material was developed to give the students involvement in the topic, starting from responses to readings and a research topic, through involvement in sustainable design and culminating with a project based on a campus building to implement the sustainability topics. The elective has been popular from an enrollment perspective, and student feedback has indicated that the course was enjoyable to the students. It has been observed that most of the students take a keen interest in the final projects, sometimes putting significant effort forth into the different measurements and reporting.

In future semesters, it is desired to open the course up to registration for not just engineering students, to give other students throughout campus an opportunity to learn about energy topics from an engineering perspective. With the importance that energy has to the future of the country and the world, it is important that not only engineers are aware of the challenges and paths available to find solutions.

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