A New Research Class as the Capstone to an Alternative Energy Minor

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Abstract

The culmination of the alternative energy minor at Robert Morris University is a capstone course which challenges the students and unleashes their creativity and enthusiasm for the minor. The course, ENGR/ENVS4112 Energy Research Seminar, focuses on the current issues of importance in the alternative energy field. Each student prepares a research paper on a specific topic of their own choosing, which is aligned with the alternative energy theme of the course. Students also present their research at the end of the semester. Students chose a wonderful selection of topics, including the energy savings and cost effectiveness of replacing refrigerators in a local hospital, the feasibility of composting on campus, the feasibility of an anaerobic digester on campus, and researching the legal feasibility of Earthships and environmentally friendly homes in the Pittsburgh region. The topics were chosen by the students and reflected their own interests and ideas of what was the most important issues. Interestingly, we had a number of students primarily interested in green engineering, the more efficient use of existing energy and recycling. The engineering students at Robert Morris University are very practical in their focus and wanted to pursue topics of research with direct real world application rather than contributing to more abstract research applications. We will discuss the development of this course, some of the wonderful experiences we had teaching the course, and future ideas for improvement.

Keywords: Alternative Energy Research Capstone Course Development

I. Introduction

Energy independence has become a huge topic in the world of U.S. politics and among many circles throughout the world. In 2010 the U.S. imported nearly 4 times the amount of energy than it exported [1]. Couple this stat with the fact that the U.S. was 2nd in the world in energy consumption in 2010, and we begin to see why energy independence as well as clean energy sources are such a concerning topic [2]. Currently traditional energy sources dominate the U.S. energy mix, but the rapidly increasing use of renewable energy has become a beacon for optimism. From 2005 to 2012 U.S. renewable energy consumption has increased by 35%, where wind energy is leading the way in terms of growth with an increase of 664% [3]. Renewable energy has entered into the forefront of many industrial and economic discussions. With such a focus on renewable and alternative energy, it becomes our duty as educators to prepare our students for a workforce where expertise in these subjects is attractive to employees.

Not only is alternative energy and sustainability important from a national perspective, but Pittsburgh, as what is becoming a U.S. energy capital, will play a large role in the development and application of renewable energies (as well as the use of fossil fuel energy sources, such as the large reservoir of natural gas within the Marcellus Shale). Therefore, a new minor in alternative energy and sustainability was developed to better prepare our students for a future workforce in clean energy and green jobs.

It is worth noting that RMU in particular is well suited to the development of such interdisciplinary programs. The Science Department within the School of Engineering Mathematics and Science (SEMS) houses a diverse range of faculty including a chemist, a geologist, an environmental scientist, four biologists and a physicist. Furthermore, the Science Department within RMU is also closely associated with the Engineering Department, which also includes a diverse range of expertise within the engineering disciplines including manufacturing, nanotechnology, renewable energy sources, and energy storage technologies. The close relations between the Science and Engineering Departments within SEMS led to this new interdisciplinary minor and remain its largest strength. Many of these courses were developed with input from a number of different faculty from both the Engineering and Science departments, and the minor continues to draw from this diverse pool of expertise. It is this interdisciplinary background, and strong vocational emphasis, that makes RMU the ideal environment for training our future workforce for careers in the alternative energy sectors, and providing local employees with science and business graduates with a strong background in environmental issues and sustainability.

On a recent visit to Pittsburgh, President Obama outlined the importance of energy: "The time has come, once and for all, for this nation to fully embrace a clean energy future. Now, that means continuing our unprecedented effort to make everything from our homes and businesses to our cars and trucks more energy-efficient. It means tapping into our natural gas reserves, and moving ahead with our plan to expand our nation's fleet of nuclear power plants. It means rolling back billions of dollars of tax breaks to oil companies so we can prioritize investments in clean energy research and development [4]."

Obama's words ring loud and clear in the Pittsburgh area. There has been an economic boom in the Pittsburgh area that is directly related to the Marcellus Shale natural gas wells. In a recent study done by researchers at Penn State University, Marcellus Shale drilling has lead to 44,000 jobs in the Pittsburgh region and has generated about $3.9 billion dollars in economic activity in 2009 [5]. The increased emphasis in energy has lead to substantial industry activity and an emphasis on green jobs in the region. According to the 2010 Milken Institute Best-Performing Cities Index, which ranks U.S. metropolitan areas by how well they are creating and sustaining jobs and economic growth, Pittsburgh was ranked 32nd in 2010, up 77 spots from 2009 [6]. Pittsburgh's emphasis is not only on creating jobs, but creating green communities and cleaning up the city. Pittsburgh is the home of the first green Leadership in Energy and Environmental Design (LEED) certified convention center (David Lawrence Convention Center) and conservatory (Phipps Conservatory) in the world, as certified by the U.S. Green Building Council [7]. In fact, as of 2012, there were 109 green buildings throughout the city, making Pittsburgh the 4th ranked city in the nation in the number of green buildings [8].

With a city-wide emphasis on sustainability, RMU has decided to do its part in educating our future workforce to increase their environmental knowledge and awareness. Through the development of a new minor in Alternative Energy and Sustainability and in addition to existing educational and outreach programs, RMU is doing its part to meet the objectives of the students and their future employers. The purpose of this paper is to focus on the capstone course for the Alternative Energy and Sustainability Minor, describing the first time that the course was taught in the Spring of 2013, the research projects that were conducted, the project outcomes, and the course teaching outcomes.

II. Alternative Energy and Sustainability Minor

The Alternative Energy and Sustainability minor is comprised of a total of 15 credits. The first 9 credits of the minor consist of three core courses which are required by all students pursuing this minor. Two of the core classes offer an introduction to the issues of energy generation and sustainability, while discussing the role of technology in addressing these issues. The final core class is a capstone class in which the students are asked to conduct a semester long research project. The remaining 6 credits are chosen from a number of upper-level courses focusing on specific areas of expertise in both science and business disciplines [9]. This increases the accessibility of the minor to the wider RMU community and introduces alternative energy and sustainability to non-science and non-engineering students. The courses which constitute the Alternative Energy and Sustainability minor are shown in Table 1.

Required Core Courses	
Alternative Energy Technologies	PHYS/ENGR 1023 (3cr)
Energy Fundamentals and Sustainability	ENVS/ENGR 1022 (3cr)
Energy Research Seminar	ENVS/ENGR 4112 (3cr)
Elective Courses	
Conventional Energy: Fossil Fuels	GEOL/ENGR 4022 (3cr)
Energy Storage, Conversion and Transportation	ENVS/ENGR 3022 (3cr)
Renewable Resources	ENVS/ENGR 2012 (3cr)
Environmental Economics	ECON 3060 (3cr)
Energy and Society	SOCI 3270 (3cr)
Organizational Viability and Sustainability	ORGL 3900 (3cr)

Table 1:Courses for the Alternative Energy and Sustainability minor at Robert Morris University

III. Course Layout and Objectives

The students, who have completed four of the lower level minor courses, including the first two required core classes, are left with the final capstone course, the "Energy Research Seminar". This course is designed to primarily consist of a semester long research project. We taught the first Energy Research Seminar course in the spring semester of 2013, and we found it to be very successful. We decided that the students should pick their own projects based on their personal interests, with the thought that students usually provide extra effort and enthusiasm when the subject is of their choosing. This also allows them to review the materials that they have learnt in previous courses taken as part of the Alternative Energy and Sustainability minor and reflect on which topics they enjoyed most. However, there will indubitably always be a small number of students who try to find an easy topic. Therefore, when allowing students to choose their own topics, we developed a list of possible topics, including community outreach projects with the University of Pittsburgh Medical Center (UPMC), Phipps Conservatory, and Zero Waste Pittsburgh. Furthermore, we discussed the topics continuously as a class. Some of the suggested topics are given below.

Research Project Topics

Students were allowed to choose any topic (subject to approval), but possible topics included

1) UPMC: Analyze laboratory equipment energy usage, determine energy efficiency upgrades and develop an economic feasibility study for the upgrades.
2) Phipps Conservatory: Energy model of the conservatory and warehouse to create a baseline. Students will compare the baseline to technologies that increase envelope efficiency to determine payback times.
3) Phipps Conservatory: Research technologies to improve energy efficiency on historic portion of the conservatory (Insulation coatings, low-e coatings, reflective materials near radiators, etc.)
4) Phipps Conservatory: Assessment of on-site Anaerobic digester for production of Biogas from sanitary waste and other organic wastes
5) Phipps Conservatory: Capture, store and use storm water from historic portion of the building
6) Zero Waste Pittsburgh: Engineering and cost analysis of converting an existing gravel parking lot to permeable pavement with bio-swales to ensure 0% (or near 0% for a 50 year storm) runoff to the storm drains.
7) Zero Waste Pittsburgh: Recycling Separator and crusher for expired canned food items (Food bank and other canned food folks in Pittsburgh).
8) Development of handouts, demonstrations and laboratory activities for the Alternative Energy Minor courses and Alternative Energy Workshop for middle and high school students.
9) Grant for funding to purchase and develop Alternative Energy Minor demonstrations and laboratories. Focus on PV, Wind and in class laboratories related to the curriculum.
10) Development of real world facts about Energy and Sustainability issues to increase public awareness and understanding of issues.
11) Feasibility study of an RMU campus anaerobic digester.
12) Outdoor laboratory design and feasibility study for the RMU nature trail, with an emphasis on sustainability
13) Other possible collaborators: Green Building Alliance and City of Pittsburgh Utilities

There were eight students in the course and they all chose different projects except for three students. Because of the sheer size of the data collection and analysis that was necessary to conduct the UPMC project, three students were requested by our UPMC colleague. These three students had to test the energy consumption for all of the laboratories in UPMC's Magee Women's Hospital.

The course met every week and the students were asked to give periodic project updates via a shared Google Document. Furthermore, we also met with the students outside of class if there were any concerns, questions or issues with their project. The students were asked to turn in a rough draft, for their midterm grade, which included a literature review containing at least 10 peer-reviewed sources. The final project paper was to be turned in at the end of the semester and was to be a minimum of 20 pages. A final project presentation was also required where the students had to present for 20 minutes and field questions afterward. Finally, a research log book was collected and reviewed to evaluate student progress throughout the semester.

IV. Student Projects

The projects that were conducted by the students during the course were:

1. An investigation of the current energy efficiency, and cost analysis for replacing, a number of electric appliances in UPMC Magee Woman's Hospital. In particular, the students analyzed refrigerators, fume hoods, incubators and ultra-low freezers. the students had to test the power consumption for a wide range of makes and models to determine the efficiencies. The cost savings upon switching to newer and more energy efficient models would allow the hospital to cover the costs of upgrading within a 5 year period (as required by the hospital administration).
2. One student investigated the use of unconventional building materials, consisting mainly of waste products, to construct homes and buildings. In particular, the student chose Lawrenceville (a local community in the Pittsburgh region) and investigated the local zoning and ordinance restrictions to such constructions. Surprisingly, there were many legal barriers to constructing green buildings from recycled waste products. However, many of these legal barriers are being removed to facilitate the construction of these environmentally friendly buildings.
3. The design of an alternative energy education laboratory. As our Alternative Energy and Sustainability minor is still very new, we have limited alternative energy outreach events or activities at RMU (although an alternative energy summer camp has been successfully ran over the last couple of years). Therefore, we had a student interested in designing a laboratory space (outside) that could be used to teach the science behind alternative energy to young children. Interestingly, the laboratory was designed to consist of a number of different activities to showcase the different technologies in a garden-like outdoor space. Furthermore, she was investigated how a school or university might get funding for such constructions.
4. The feasibility of building an anaerobic digester on campus. A student was interested in the financial benefits of anaerobic digestion in terms of the biogas and fertilizer produced, and the reduction in food waste. The cost of reducing food waste, in terms of the waste management costs, was estimated along with the cost of commercial fertilizer

(used to fertilize the campus grounds). Second, the biogas produced could also be used to reduce heating and this was estimated to have a (small) cost benefit. Next this cost benefit was contrasted with the cost of building and maintaining an anaerobic digester on campus. While it was found that such an anaerobic digester would not necessarily be financially feasible, the educational benefit of having such a system on campus was believed to be high.

5. Harvesting wind energy from pre-existing structures. A student wanted to investigate the amount of wind energy that could be extracted from pre-existing structures (such as street lights for example). A digital anemometer (also capable of measuring other weather related phenomena) was used to calculate the air speed in urban environments around campus. In particular, the winds speed on top of a couple of street lights were contrasted with other urban regions. The kinetic energy that could be extracted from placing wind turbines in such regions was found to be very small.
6. Composting on campus. A student looked at the different methods for composting and how they might be applied to RMU campus. In particular, the food and other wastes were considered along with the climate in our region and associated costs. No conclusions were drawn.

VI. Course Outcomes

The students, for the most part, were very enthusiastic about the course and had a great time exploring the project of their choice. Throughout the course we stressed the need for creativity and intuition, but at the same time tried to keep the students grounded to the pre-existing literature, when necessary. This was decided very early in the planning of the course, which is why we enforced students to submit a draft report midway through the semester containing an introduction mainly consisting of a literature review, and a methodology consisting of how they propose (or currently were) conducting their experiments. Furthermore, the students were not working in isolation on their projects. When the class met, we would go around the classroom for informal presentations and discussions on all of the projects. In particular, the students were asked to stand up and to talk for a few minutes on their project. Other students then had to ask questions concerning other peoples research projects. Often a research project benefitted from the ideas and input from many students at these meetings, and the discussions were always entertaining and informative.

A lot of emphasis, in terms of our teaching of the course, was spent discussing how the experiments (when applicable) would tell a story. For example, a student would often propose to conduct an experiment, and obtain data, but not necessarily realize that the data would have to be presented in a way that would tell a story when included in their final report. The lack of experience often led students to not take into consideration how the final paper might look until they were actually writing the final paper. To combat this tendency, we first handed out copies of scientific journals and discussed the style of writing and the form of the graphs and data in the articles. This gave students an idea of what they would produce in their final report. Second, while students were discussing their progress and proposed future activities (as part of our weekly meetings) we would push them to be more specific about the details of the numbers they were looking to obtain. In particular, we occasionally asked students to go to the whiteboard and draw how they expected their results to look ahead of time. This made the students think about

how their experiments might tell a story ahead of time, and further developed their intuition and insights into their projects.

Finally, the students gave in class presentations (and were allowed to invite their friends from outside of class to the talks). The students were each given two marbles at the beginning of the talks and were told that they would lose a marble upon asking a question. The rules of the game were that they must lose their marbles before the end of the talks. The purpose of this game was to ensure a thorough discussion, and interestingly we found that once students started asking questions that many of the students would get into the spirit of the talks and ask many more than just two questions. However, we found that forcing students to ask questions is a wonderful way to get the ball rolling (or marbles rolling). The highlights of the talks were the presentations, and the discussions that were initiated as part of the presentations. A couple of students did so well that they were invited to give their presentations at a university wide student research conference.

VII. Conclusions

To conclude, the course was an immense success and a joy to teach. The success of the course was almost entirely due to the caliber and enthusiasm of the students and as the faculty teaching the course we can't take much credit. However, we feel that the course was an excellent mechanism to foster the creativity and inspiration of our students, and that the organization of the course and its assessments should remain intact for future offerings. However, the first time a course is taught there will always be things that can be improved upon and in this course we believe that the next time the course is taught we will implement of the following changes:

1. The final presentations, while open to the friends of the students, weren't attended by many people outside of the class (with only one other faculty member in attendance). This was in part due to the class being held in the evening and at the end of the semester. However, we feel that this event could have been more widely attended and we will look to make this event more of a party atmosphere in future. For example, we could provide food and beverages, or even consider having the presentations outside or off campus. Having the students give the presentations as a community event and inviting members of the community onto our campus for the presentations might also be an option.
2. Two of the projects - the projects involving anaerobic digestion and composting - had considerable overlap as the projects were looking at the same source of material (principally food waste from the cafeteria). In the future, we will limit the projects to ensure that there is no such overlap.
3. Bringing in guest lecturers that are experts in fields that are related to one or more of the student project topics would be another way to enhance the course. This could also provide a possibility for an expert advisor that could assist the student when needed.
4. In order for the students to get a better idea of how a research topic is developed, a literature search is conducted, the methodology is created and the general report writing

process, it would be advantageous for the student to read a Master's student thesis in a related field. Reading a Master's thesis will help the students to understand the process and development of research project.

5. Finally, the continuation and expansion of real-world projects where the students are able to work with a professional or outside researcher on a project would offer the course added value. The students that worked with a professional from UPMC learned a lot beyond the research project itself and they were able to make some valuable networking connections

Overall the course was a success and with some additional improvements, we think that this course can be very beneficial for the future careers of the students who take the course.

References:

[1] International Energy Agency - United States Energy Balances for 2010, accessed: 9/6/13. http://www.iea.org/statistics/statisticssearch/report/?&country=USA&year=2010&product=Balances

[2] The World Bank - 2010 Energy Use Data, accessed: 9/6/13. http://data.worldbank.org/indicator/EG.USE.COMM.KT.OE?order=wbapi_data_value_2010+wbapi_data_value&sort=desc

[3] U.S. Energy Information Administration - U.S. renewable Energy Consumption, accessed on 9/6/13. http://www.eia.gov/forecasts/steo/tables/?tableNumber=24#startcode=2005&endcode=2012

[4] Bill Schackner, Katie Falloon, "Obama touts economic, energy policies in CMU speech," Pittsburgh Post-Gazette (June 02, 2010).

[5] Timothy J. Considine, Robert Watson, Seth Blumsack, "The Economic Impacts of the Pennsylvania Marcellus Shale Natural Gas Play: An Update," (2010), accessed on 9/6/13. http://marcelluscoalition.org/wp-content/uploads/2010/05/PA-Marcellus-Updated-Economic-Impacts-5.24.10.3.pdf

[6] Milken Institute, "2010 Milken Institute Best-Performing Cities Index ranks," accessed: 9/6/13. http://www.milkeninstitute.org/

[7] Leadership in Environmental Sustainability, CMU-BCA Executive Development Program 2011." http://www.bcaa.edu.sg/enews/201101/pdf/CMU_draft6.pdf

[8] "Green Building Rating System," Pittsburgh Today, http://www.pittsburghtoday.org/view_GreenBuilding.html

[9] RMU Alternative Energy and Sustainability Minor Course Outline. http://www.rmu.edu/OnTheMove/wpmajdegr.get_results_majors?ischool=U&idegree=NX&imajor=AEAS&it=&ipage=3034&iattr=&icalledby=WPMAJDEGR

Appendix 1: Cover of the Alternative Energy Minor Brochure

Appendix 2: Inside of the Alternative Energy Minor Brochure