Renewable Energy Projects for Teaching Humanitarian Engineering

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***Abstract* - There is growing interest among students in power generation technologies which offer reduced carbon emissions compared to the burning of fossil fuels. There is also a strong interest in the present generation of students to perform project work which offers the opportunity to provide betterment of peoples' lives. Over the last 20 years we have conducted a wide range of renewable energy-related projects including solar water pumping designs, solar lighting systems, solar electric car projects, and data acquisition systems for solar electric systems. Details of these projects and their utility in teaching humanitarian engineering will be described in this paper.**

Index Terms – humanitarian engineering, renewable energy, solar energy, student projects

INTRODUCTION

Present day engineering students are very interested in seeing development of technologies to help mankind, particularly for people in developing nations. Also, students are growing more concerned about global warming and the impact of burning of fossil fuels to meet the growing energy needs, again primarily in developing nations. A third motivation for the present project is the need to train students in the growing renewable energy business. Wind and solar deployment has been growing at about 40%/year compounded annual growth over the last five years! Finally, many of the renewable energy projects offer real-world, hands-on experience for the students working in inter-disciplinary teams. Several programs incorporating service learning have been developed over the last few years including the EPICS program at Purdue University [1], the IPRO project at the Illinois Institute of Technology [2] and service learning projects at the University of Massachussetts at Lowell [3]. Indeed, John Duffy has used service learning to teach about solar energy [4]. Service learning engineering organizations, such as Engineers without Borders, are also growing in popularity on campuses [5]. Catherine Skokan at the Colorado School of Mines has extended service learning education to the offering of a Minor in Humanitarian Engineering [6].

As a Catholic Augustinian University, Villanova University prides itself on reaching out to the poor and less fortunate. The University's Campus Ministry office has connections with several different missions all over the world and offers various forms of service learning opportunities including Special Olympics, an Olympics-type event for handicapped children, Habitat for Humanity, a program that provides homes and shelters to the poor, and various health education outreach programs to poor communities. In the College of Engineering the Civil and Environmental Engineering Department and Mechanical Engineering departments have been taking regular mission trips to Nicaragua and Honduras for working on construction projects including building of schools and community centers and laying water distribution systems. An Engineers without Borders chapter was also established at Villanova University three years ago.

Over the last twenty years, in the Electrical and Computer Engineering department we have worked with over 100 students on renewable energy related service projects. Many of these projects have involved interactions in developing countries and as a result have exposed students to global issues, such as different languages, cultures, and work environments, important topics in today's globally integrated engineering enterprise. Examples of these projects and their impact on students are presented in this paper.

RENEWABLE ENERGY PROJECTS

Solar Car Project

In 1989 two student projects were performed that provided a strong impact on the student participants. The first was a college-wide project to develop and race a solar electric car in the 1990 GM Sunrayce. This was a transcontinental race from Disney world in Florida to General Motors' Tech Center in Warren, Michigan. The project involved designing, building, and financing a solar electric car that could run on normal roads with a chase car and lead car sandwiching the vehicle. The car design involved teams of mechanical and electrical engineering students and faculty working together and was a challenging project. The students spent an enormous amount of time on the project designing, building and constructing the vehicle. A photograph of the completed car is shown in Figure 1.

It was a very exciting project and the competition of the race and pride in the university highly motivated the students to perform at their best. Although some initial testing was done prior to the race, the car was not fully tested before going

FIGURE 1
PHOTOGRAPH OF SOLAR CAR DESIGNED AND BUILT BY VILLANOVA UNIVERSITY STUDENTS

down to Florida for the start of the race. We were still working on array-related problems and troubleshooting problems with the peak power trackers for the solar panels. We ended up losing the race but the hands-on engineering that the students experienced was incomparable. They learned so much about project management, teamwork, energy efficiency, electrical and mechanical engineering, and project financing. One of the electrical engineering students on the team still works in the solar energy field. However, this project was also very demanding in terms of student and faculty time and fundraising took a huge amount of time and effort. Furthermore, this type of project, although providing an excellent engineering experience, taught little to the students in terms of the potential impact of solar energy on peoples' lives.

Water Pumping Project in Dominican Republic

On the other hand, in 1989, I accompanied a student working on a senior design project to design and install a solar water pumping system in the Dominican Republic. I had met Richard Hansen at a conference on the use of solar energy in rural development. Richard was running a non-governmental organization (NGO) in the Dominican Republic providing micro financing and training technicians in the deployment of solar electric systems in rural parts of the Dominican Republic which were not connected to the national grid system. My student and I stayed with a Peace Corps volunteer in the village of Bella Vista where the only source of electricity was solar power! Small (~50 Watt) solar panels were being used to recharge batteries to power lights and television sets in homes in this village. We accompanied villagers, women primarily, to collect water from a creek. The walk to and from the creek was a few miles and, of course, the women were carrying water on the way back in one gallon containers. Walking several miles in their footsteps certainly gave us an excellent appreciation for the effort involved in providing water to the local villagers on a regular basis. While Richard had the interest and motivation to develop solar water pumping facilities for the village, he did not have the technical expertise to carry out the design.

Two electrical engineering students, one of who accompanied me on the site assessment trip, designed the water pumping system based upon an estimate of the depth of the water table. After the well had been drilled, it turned out that the water table was at a deeper location than had been estimated and so the final design had to be modified. Nevertheless, the modified student design was implemented and provided a transformational experience to the student who went on the trip. He was forced to revisit his high school Spanish! He experienced the passion for baseball in the Dominican Republic! Most of all, he learned that many people in the world live off far less and under much harder conditions than he could have appreciated without traveling down there as part of this project experience.

Bioreserve Project in India

Over the last two years, I have supervised four additional projects related to solar electric systems for developing countries. One emanated from an Engineers without Borders project in which students were asked to design a solar electric system to provide power to certain loads to a Bioreserve located in Tarumitra in the state of Bihar in India. The students had to first learn details about the Bioreserve and compute the loads that were required to be met by the solar electric system. As the students designed the system and gained knowledge of the cost of solar electricity and the efficiency of the loads, they needed to learn how to maximize efficiency and optimize the design to minimize cost. Although the students did not travel to India for this project, they certainly learned a lot about how little electricity is typically used in developing nations compared to the US. Furthermore, the students interacted with a solar module manufacturer/system integrator, Tata/BP Solar. The communication with Tata/BP Solar exposed some cultural differences between the way business is done in the US and India. It was a very interesting experience for the students.

Data Acquisition System for Solar Power System for Poultry Farm

A second project supervised in the 2004-2005 academic year was the design of a data acquisition system for a solar electric system for a poultry farm. The farm receives chicks when they are only a few weeks old and raises them until maturity. These hens are primarily raised for laying eggs. Their growth is optimized by carefully controlling both the lighting and temperature inside the shed. The particular farm that we studied was Little Buck Run Farm in Parkersburg, Pennsylvania. This farm had two identical sheds and the research project that this design project was supporting was the replacement of inefficient incandescent lighting with high efficiency solid state (LED) lighting and the replacement of inefficient fans with variable speed drive

fans. By having two identical sheds, the power savings of one shed over the other could be quantified. The student project therefore involved the design of the lighting and cooling systems and their respective control systems. The students learned a lot about sensors, efficiency of loads, and the design and costs of solar electric systems. While again this particular project did not particularly lend itself to humanitarian engineering, it educated electrical and computer engineering students in renewable energy and energy efficient technologies which they can incorporate into their future careers.

Water Pumping System for El Guabo Community in Waslala, Nicaragua

A third project involved the design of a water pumping system for the community of El Guabo in Waslala, Nicaragua. The present water source to this rural community is contaminated by fecal waste from grazing animals and therefore results in water-borne illnesses being spread in the community. The goal was to design a solar water pumping at an elevation above the grazing line of the animals. The project was worked on by a team of five students, three of who had been on a mission trip to Waslala. During the mission trip the students both interacted with the local people, mostly through interpreters, and helped lay a gravity feed water distribution system, also from a higher elevation. The students were treated very warmly by people in the local community who had very little material possessions. The students were provided opportunities to reflect on their experiences as a part of the visit. While this project design did not get implemented, the students still found it very valuable as a maturational experience.

Water Pumping System for Orphanage in Honduras

A fourth project that students worked on this past academic year was the design of a solar water pumping system for an orphanage in Honduras (see Fig. 2). The orphanage is run by a Catholic missionary and has a relationship with Villanova University's Campus Ministry. The initial phases of the project involved performing an assessment of the existing water supply and power system. The power is provided by a hydroelectric power plant through a grid system. However, during the dry season, the hydroelectric power plant's output decreases and the power supply to the orphanage becomes very unreliable. In the rainy season, the power supply is quite reliable. This proves to be an ideal situation for a solar electric implementation to provide backup power to the water pumping system. During the Spring 2006 term, two mechanical engineering students went down to visit the orphanage as part of a mission trip from Villanova. They took a number of pictures and did some basic site assessment for locating the solar electric system. They also obtained some data about the pump and storage tanks (see Fig. 3). A team of electrical and mechanical engineering students (including the two mechanical engineering students who went on the trip to Honduras) worked on the design of the solar electric system to provide the back up power to the water pumping system. Also, they worked on expansion of the system to support a larger community since there were plans to develop a school and increase the catchment area for the orphanage. However, there were a number of questions that were unclear to the electrical engineering students regarding the system specifications. They made a trip down to Honduras to determine for themselves more details about the existing system. While there they also took a trip to a local town where a solar distributor was located. Through an interpreter they were able to determine the availability of different solar components, their costs, etc. The students also again learned some of the difficulties in doing business in a culture different from what they are used to, particularly in terms of communication with someone in a different language. Once more, the students found the interaction with the orphanage children to be transformational and one of the students has decided to now pursue a master's degree under my guidance focused on renewable energy systems.

FIGURE 2
OVERVIEW OF AMIGO DE JESUS ORPHANAGE, HONDURAS

FIGURE 3
PICTURE OF WATER STORAGE TANK SHELTER

CONCLUSIONS

The student projects described in this paper fit very well into the mission of a Catholic, Augustinian university where service to the poor is a central theme to the university's mission. Villanova University's motto is "Transforming Minds and Hearts". While our emphasis in engineering disciplines is usually focused on the mind transformation component of this motto, the service learning engineering experiences focus on the heart transformation. Renewable energy projects, such as those described above, have a strong electrical engineering design component to them and yet provide students a valuable lesson on the potential impact of technology on people's lives, particularly for those with much less access to energy than the students. The humanitarian engineering component of this work is both inspiring and motivating for the students. With the growing opportunities for students to be able to work in the renewable energy field after graduation, this area will continue to offer unique opportunities to simultaneously prepare students for an emerging technological discipline and experience the potential for serving humanity through the ubiquitous availability of clean energy sources.

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