Project-Based Curriculum for Renewable Energy Engineering Technology

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Summary

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University of Tulsa 1997 Northeastern Oklahoma 1995

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Editor of assorted letters, memos, brochures, academic papers and other projects of university staff members.

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Cyril B. Okhio is currently an Associate Professor in the School of Engineering at Southern Polytechnic State University. Dr. Okhio earned his B.S. (General Engineering) and Ph.D. (Mechanical Engineering) degrees from the University of London. He was also a Science & Engineering Research Council SERC Post-Doctoral research Fellow at the Aeronautics Lab, Queen Mary College for three years. He is registered as a Chartered Professional Engineer with the Council of Registered Engineers, United Kingdom; a

Member of the Institution of Mechanical Engineers, UK and a Member of the Institute of Transportation Engineers, USA. Dr. Okhio has many years of administrative experience including the Chairmanship of the Mechanical Engineering Department, Bendel State University. Dr. Okhio has carried out experimental and numerical investigations of, and developed statistical analysis tools and computer codes, for the calculation of complex flows. Some of this work has been published in international journals. He is currently involved in multidisciplinary research and development concerning Vehicle to Vehicle, Human to Vehicle Interaction and communication, under the purview of a Transportation, Vehicular Systems and Safety Engineering hub associated with SPSU Visualization & Simulation Research Center for which he is a co-PI. Dr. Okhio is very familiar with the level of technology and development, world-wide. He has visited many countries including Taiwan, Japan, Saudi Arabia, Zambia, Zimbabwe, Ghana, Senegal, Belgium, Germany, Austria, Italy, France, and he lived in the United Kingdom for more than 12 years. He is married with two children.

Project-Based Curriculum for Renewable Energy Engineering Technology Undergraduate Program

Abstract: This paper presents a novel approach of instruction for the Renewable Energy Engineering Technology program, emphasizing design and implementation techniques that complement traditional teaching methods. Course and laboratory development are discussed, and project selection and management is emphasized. This analysis was done to predict the effectiveness of project-based instruction for programs related to power generation, in general, and to renewable energy, in particular.

Two different courses were examined and their course learning outcomes compared to the expected, statistically predicted outcome. Both courses were structured as lecture-lab-project, where the laboratory experiments were sufficient in number and complexity to consolidate the topics addressed during lectures, while the projects selected were intended to cover sufficient number of topics addressed through the first half of the course, as the topics covered in the second half of each course could have not be feasibly implemented, due to financial and time constraints. Throughout this work, extensive literature review on the topic of technical curriculum development was employed.

This research shows that project oriented courses, when well timed with lecture and laboratory sessions, constitute an advanced teaching method as compared to traditional lecture-lab schemes. This approach has demonstrated its added value to courses in the Renewable Energy Engineering Technology concentration, where implementation of design is generally the trademark of Engineering Technology programs. Consequently, project reports and technical presentations, associated with each individual project, underline the set of skills characteristic to graduates of Engineering Technology programs. This research demonstrates the clear advantage of lecture-lab-project structured courses of Renewable Energy Engineering Technology as opposed to the more traditional method lecture-lab course structure.

Introduction

Bentley and Kyvik, 2012 found in their studies that faculty members spend more than 50 hours of their time every week on the job, out of which only 20 hours are spent doing the actual teaching. Depending on the faculty status, either Freshman or Tenured, or even as a function of the nature of the institution in which you find yourself, research oriented or purely teaching institutions as the case may be, these hours can be much higher.[1]

We would need to inculcate time-efficient teaching practices into these new courses from here-on in order to give the students the best and facilitate their learning in these new fields. To do these, according to a recent article by Linda C. Hodges, Associate Vice Provost for Faculty Affairs, Director, Faculty Development Center, University of Maryland, we would need to address three basic best practices that can have positive impact on the way we present the course that will emerge in the areas of Renewable Energy, heretofore:

1. Begin with the end in mind.
2. Generate criteria or rubrics to describe disciplinary work for students.
3. Embed "assessment" into course assessments.

An investment of substantial time up-front will enhance the effective teaching of these new courses and this should be encouraged across the board. Spending time on intellectually rewarding exchanges on the subject of Renewable Energy with students, on a regular basis, while we highlight current events and news on the subject matter, is recommended. Remember that when a student has learnt and shown understanding, a teacher must have done his or her job well.[2,3,4]

Courses development, within the renewable energy curriculum, are generally more challenging than core course and/or discipline-specific course development. This unique characteristic is due to the dynamics specific to the field of renewable energy and of its cross disciplinary nature.

The projects selected for each course were of adequate complexity and proportional with the number of students enrolled in each course. Due to time constraints, and to limited financial capability, all projects were small-scale or proof of concept, with two exceptions, were local industry support was received. The projects selected were intended to complement and consolidate the topics covered in each course.

The Engineering Technology discipline is defined as the part of the technological field that requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer.[5,6] Previous research on project-based instruction shows that the ABET required competencies, for engineering technology programs, are better implemented through project based instruction. [5] It was determined by other research teams, that project based instruction is an extremely effective method of learning the fundamentals and understand how engineering principles are applied to solve design problems.[7] Project –based learning approach, implemented at the freshmen level as a comprehensive group project, stimulated the overall interest of the students in the subject studied, as the project provides a practical application of engineering fundamentals learned in the course.[8] As compared to lecture + lab format, project based learning (lecture + lab + project) shows a measurable improvement, shifting the learning process from a teacher-driven to a student needs focus.[7,8]

Similar to Design-Spine method, project-based learning addresses the set of competencies underline in the ABET accreditation requirement for engineering and engineering technology programs. Both methods emphasize professional practice of communication skills, team work, project management and economic design, enhancing the understanding of science, engineering fundamentals and problem solving skills.[9]

Importance of this study

This research main purpose is to demonstrate the effectiveness of lecture + lab + project structured courses in the Renewable Energy Engineering Technology program, as opposed to the more traditional method lecture + lab course structure, in achieving the student learning outcomes set for academic programs focused on Renewable Energy.

Constraints

This research was limited to the study of student learning outcomes for two courses within the Electrical Engineering Technology program, Renewable Energy concentration.

Courses studied

The two senior-level courses studied in this research were:
a) Alternate Energy (ECET 4550)
b) Wind Energy Systems (ECET 4904).
For each course, the measured learning outcomes were compared to the expected, statistically predicted outcomes, to determine if project-based instruction would improve student learning.

a. Alternate Energy Course, ECET-4550

This course introduces students to alternative forms of energy generation, storage and delivery. The class explores present day technologies using oil, coal and gas, then, moves into emerging technologies such as solar, wind, waves, tidal, geothermal, etc. Storage technologies such as batteries and flywheels are also being addressed, along with fuel cell delivery techniques. The course concludes by exploring more futuristic possibilities such as space-based solar and high-altitude wind generation. Four laboratory exercises are used to reinforce lecture concepts introduced during the semester. Students were required to write formal reports for all of four laboratory exercises.

Students were required to conduct an independent project design and implementation on a topic of alternative energy application, consisting of: appropriate literature review, investigation of alternative designs, simulations, construction of prototypes or scaled functional models, experimental data collection and analysis of results. Each project was presented, in a power-point format, to an audience comprised of faculty, students, and staff. Each presentation was evaluated, based on content and format, and was used to compute the final grade for each student. Since Alternate Energy course is one of the elective courses in the capstone-courses pool, formal project reports were required from each student and formed part of their final grade.

Ten projects were assigned in this course, with two or one student per project, with a total student enrollment in this course of twelve (12) students:
1. Solar Tracking System
2. Application of Solar Energy Storage and Recovery for Remote Residential Locations

3. A Novel Approach in Solar-Thermal Energy Generation and Conversion
4. Solar-Powered Air Conditioning Unit for Automotive Applications
5. Green-Powered Cooking with Parabolic Solar Cooker
6. Elevation-Azimuth Sun Tracking System
7. Five-Blade Horizontal Axis Wind Turbine
8. Solar Hat with Cooling Fan
9. Small-Scale Stirling Engine Power Generation
10. Electric-Assist Bicycle

A summary of each project for Alternate Energy course (ECET 4550) is included in the Appendix A.

b. Wind Energy Systems Course (ECET 4904)

This course presents the fundamentals of wind turbines and wind power systems, covering the principles of fluid mechanics, aerodynamics, energy conversion concepts, and connection of wind energy systems to the electric grid. The design, operation, and the characteristics of propeller-type wind turbines (HAWT); two-blade, three-blade, and five-blade configurations, and vertical-axis wind turbines (VAWT) such as; Darrieus, Savonius, and Gorlov are presented. The course concludes with topics related to the environmental impact of wind energy systems and safety issues associated with wind turbines installation, operation and maintenance, as well as economics of wind turbine parks.

As part of course learning objectives, students were required to conduct independent literature review on wind energy applications, investigate alternative designs of wind turbines, design, construct and test proof of scaled-down wind turbines in the wind tunnel. Computer simulations were compared with experimental data, and analysis of results was included in a written report. Each project was presented, in a power-point format, to an audience comprised of faculty, students, and staff. Each presentation was evaluated, based on content and format, and was used to compute the final grade for each student. Although this course is not included in the pool of capstone-level courses, a written report was required of each student, to evaluate technical writing skills on renewable energy projects/topics.

Six distinct projects were assigned, with one or two students for each project, at n overall enrollment of nine (9) students in this course:
1. Characteristics of a Three-bladed Savonuis Wind Turbine
2. Study of the Savonius Wind Turbine with Air-Gap
3. Characteristics of a Dual-Stage Savonius Wind Turbine
4. Characteristics of Two-Blade Horizontal Axis Wind Turbine
5. Characteristics of Three-Blade Horizontal Axis Wind Turbine
6. Characteristics of Five-Blade Horizontal Axis Wind Turbine

A summary of each project for Wind Energy System course (ECET 4904) is included in the Appendix B.

Project presentations, in power-point format, were evaluated on the following criteria:
a. Student appearance/dress code
b. Use of proper English
c. Smooth flow of information
d. Clear statement of the problem
e. Objectives clearly stated
f. Adequate technical content
g. Data accuracy
h. Proper font size and proper contrast of power-point slides

A. Analysis of results for the Alternate Energy course

Students' work was evaluated in two formats: project report and project presentation. The report was evaluated based on the standard APA format, content, and accurate technical information. Literature review and references cited was critical. Computations and simulations were evaluated for accuracy and consistency.

Test questions, final exam questions, and project report results, as specified in Table 1, were utilized to assess the course outcomes. Since four of the seven course outcomes measured achieved a satisfactory level, it is concluded that the course needs to be restructured and improved to maximize student learning outcomes. The results for the Alternate Energy course are compiled in the table below.

	Intended Course Outcomes	Performance Criteria (Satisfactory Level of Achievement)	Assessment Results (Measured Level of Achievement)
ECET 4550, Alternate Energy	1. Demonstrate a fundamental understanding of energy and power by solving energy/power problems relating to energy transfer, energy efficiency, and energy conversion	70% of students score 70% or higher (Lab-1: Energy Assessment)	100% scored 70% or higher (Lab-1: Energy Assessment)
	2. Be able to identify and describe the major sources of energy used in society today	70% of students score 70% or higher (Exam-1, Question-2)	53% scored 70% or higher (Exam-1, Question-2)
	3. Be able to identify and describe emerging and possible future sources of energy in our society	70% of students score 70% or higher (Exam-3, Question-7)	69% scored 70% or higher (Exam-3, Question-7)
	4. Demonstrate the ability to	80% of students score 70%	69% scored 70% or

	analyze energy as a complex system	or higher (Exam-3, Question-5)	higher (Exam-3, Question-5)
	5. Be able to construct a working physical model of energy conversion, energy storage, or energy utilization	70% of students score 70% or higher (Lab: Project Implementation)	85% scored 70% or higher (Lab: Project Implementation)
	6. Present an energy alternative project in front of an audience	70% of students score 70% or higher (Project Presentation)	85% scored 70% or higher (Project Presentation)
	7. Effectively communicate technical aspects of renewable energy project in a formal written report	70% of students score 70% or higher (Final Exam, Report)	85% scored 70% or higher (Final Exam, Report)

Table 1: Student learning outcomes for ECET 4550 course

Analysis of pre and post project on essential course objectives

Comparison of student learning on essential topics was conducted as pre and post project completion and presentation. Relevant questions were present in term-examinations that proceeded the project presentation session. Similar questions were included in the final examination, which was administered one week after the project presentation session. The results are shown in figure 1.

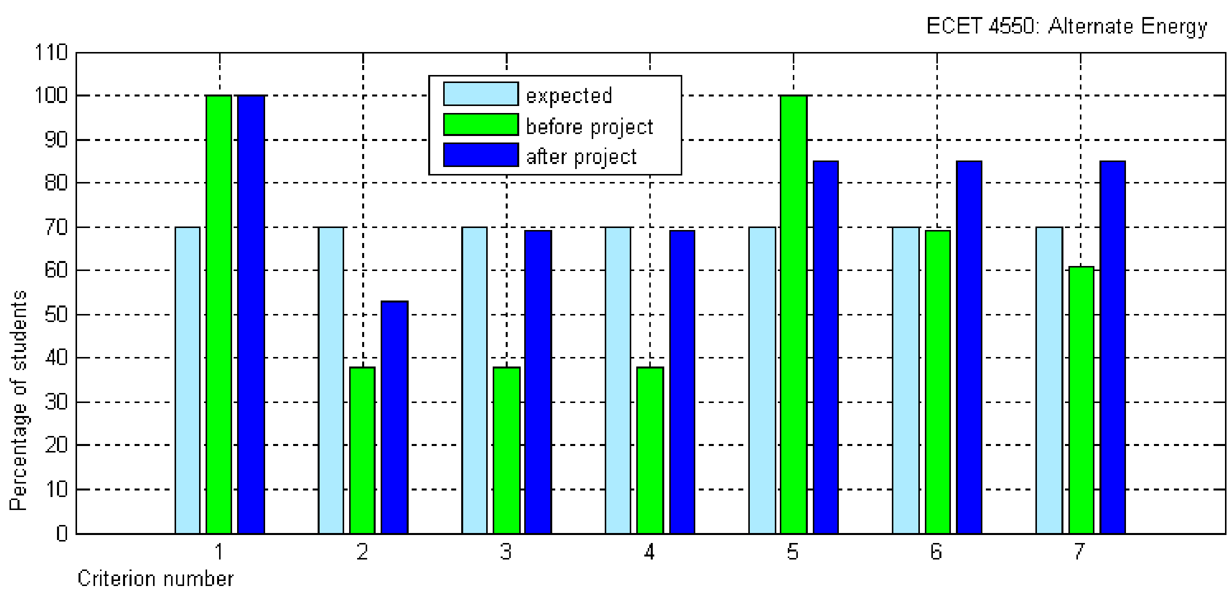

Fig1: Comparative results of pre and post project learning outcomes, ECET 4550

Student Feedback for the Alternate Energy Course

Several students commented on value and the importance of capstone projects, emphasizing the employment opportunities associated with some projects. Comments from most students indicated the difficulty in concluding all tasks associated with the capstone project in such a small time frame, as well as the constructive aspects of their respective projects, such as: proper materials, machining of critical parts, etc.

B. Analysis of results for the Wind Energy Systems course

Course Modifications and Results: The required text, *Wind Turbine Technology*, by Ahmad Hemami, released by Delmar, Cengage Learning, in 2012 was first time used. Since the textbook was designed primarily for lower-level courses, the textbook lacks mathematical detail, while the wind turbine design is not adequately covered. Consequently, additional material related to wind turbine design, power electronics, power system control, and power system protection from different texts was used to complement the textbook material. The lack of laboratory equipment transformed the course in a project-based course, where the lab time was used to explore wind turbine systems, with constructive dialog, under the instructor supervision. There were four to five lab sessions dedicated to learning specialized software for mechanical design (Solid-Works), and power system control (Power-World). The other six lab sessions were used for the design and construction of small Savonius wind turbines. Overall, the project-based method used in this course was well received by the students.

Communications Component: A written wind turbine project report was required, as part of the final exam grade, the other part being an oral presentation of the project, with design component and discussion of wind turbine performance. There were six teams (with three students per tem), each team required to analyze, design and test one particular type of wind turbine. Each individual student was evaluated based on his contribution to the project, and his skills to communicate specialized technical information to an audience.

Ethics Component: While not included in the objectives of this course, given the specific topic of this course, it was determined that one lab session should be dedicated exclusively to professional ethics. Thus, an “Ethics Workshop”, design by the instructor, was conducted, emphasizing case studies. Ethics component were included within the objectives and the topics of this course.

Course Assessment and Results: Since five of the eight course outcomes measured achieved a satisfactory level, it is concluded that the course needs adequate equipment (wind turbines) and a higher quality textbook should be adopted to maximize student learning outcomes.

	Intended Course Outcomes	Performance Criteria (Satisfactory Level of Achievement)	Assessment Results (Measured Level of Achievement)
ECET 4904, Wind Energy Systems	1. Describe the operation of a horizontal-axis wind turbine, HAWT.	70% of students score 70% or higher	67% scored 70% or higher (Exam-1, Final Exam)
	2. Describe the operation of a vertical-axis wind turbine (VAWT)	70% of students score 70% or higher (Exam-2)	78% scored 70% or higher (Exam-2, Final Exam)
	3. Describe the principles of operation for grid-connected wind turbines	70% of students score 70% or higher	78% scored 70% or higher (Exam-1, Final Exam, Question-8)
	4. Determine the financial feasibility of wind farms in a given geographical area	70% of students score 70% or higher	44.5% scored 70% or higher (Exam-2, Final Exam)
	5. Design single-turbine and multiple turbine wind generation systems	70% of students score 70% or higher	78% scored 70% or higher (Quiz-5, Lab Report 4 and 5)
	6. Describe the safety guidelines when installing, maintaining, and troubleshooting wind turbines	70% of students score 70% or higher	67% scored 70% or higher (Exam-3, Quiz-5, Final Exam)
	7. Determine the apparent power, reactive power, and power factor correction for a small wind farm.	70% of students score 70% or higher	78% scored 70% or higher (Exam-3,Final Exam)
	8. Design, construct, and test a small wind turbine.	70% of students score 70% or higher (Final Exam)	100% scored 70% or higher (Final Exam, Question 6, 7, 8 and 9)

Table 2: Student learning outcomes for ECET 4904 course

Analysis of pre and post project on essential course objectives

Comparison of student learning on essential topics was conducted as pre and post project completion and presentation. Relevant questions were present in term-examinations, which preceded the project presentation session, and the same questions were included in the final examination, which was administered one week after the project presentation session. The results are shown in figure 2.

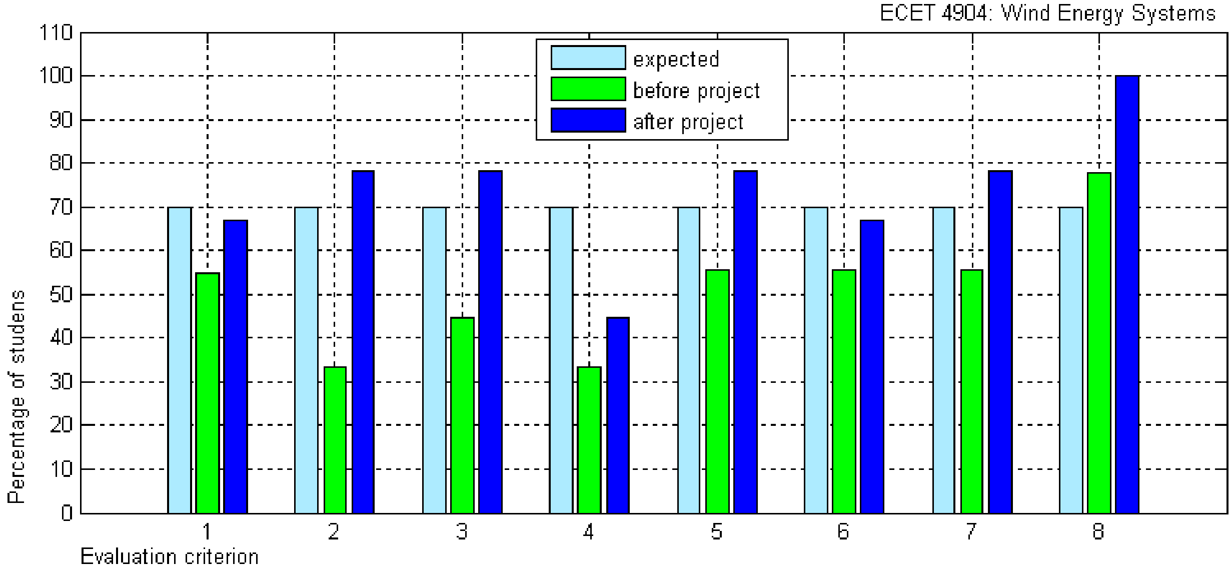

Figure 2: Comparative results of pre and post project learning outcomes, ECET 4904

Student Feedback for the Wind Energy Systems course

While the 3D printer was not available to construct the scaled models of all wind turbines, their design was done with Solid Works, and couple turbines were, in fact, constructed/"printed" four months after the course was concluded. However, each team has successfully found viable alternatives to construct their assigned wind turbine, and performed appropriate testing and measurements.

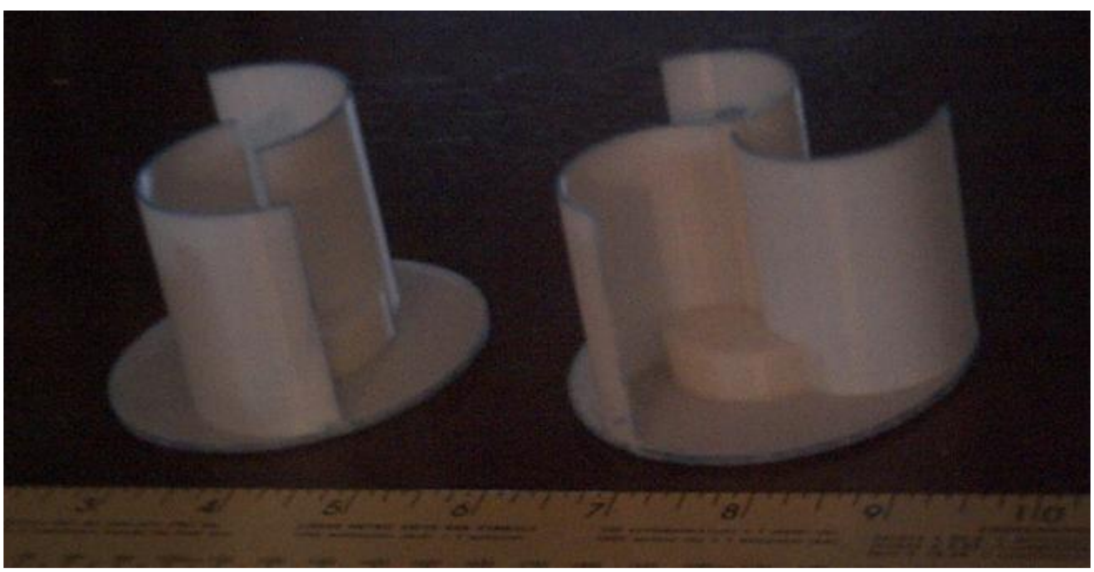

Figure 3: Three-blade and Air-gap two-blade Savonius micro turbines

Comments from students were used to re-address topics of increased difficulty, as well as topics related to student laboratory/projects. Of main importance were topics related to professional ethics, brainstorming, and proper team work that were emphasized during each laboratory session. To better benefit from a project-based course, the selection of a wind-turbine project needs to be made within the first two weeks of class, as to accommodate eventual mishaps and/or change of project topics (for various reasons).

Conclusions and future work

Project reports and technical presentations, associated with each individual project, underline the set of skills characteristic to graduates of Engineering Technology programs. This research demonstrates the clear advantage of lecture-lab-project structured courses of Renewable Energy Engineering Technology as opposed to the more traditional method lecture-lab course structure.

Consistent with students' comments, projects assignment will contain strict milestones, and will be done in the earlier part of the semester. Based on the project-based learning success, it is strongly recommended to preserve the end-of-course project format (written report, demonstration of functional system, and oral presentation) as the final comprehensive examination.

Considering the project-based course format, it is preferable to have the course material covered earlier in the semester, concomitant with project selection and preliminary design, then project implementation, testing and presentation, conducted during the last half/third of the semester.

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Appendix A:

Selected Project Summaries for the Alternate Energy course (ECET 4550)

Elevation-Azimuth Sun Tracking System

"This project addresses the need for an alternate power source of an electronic device which requires 12VDC to perform its functions. The electronic device is a Telguard TG-9, which falls under the fixed wireless device family. Its basic function is to send wireless notifications via six output relays that are programmable. These relays can be connected to an external device that changes the state of the relays thus sending a notification to a central monitoring company as well as any device that can receive a basic text message. These units are used in various environments, in remote locations with no electric power from the grid, thus maintaining power is the most problematic issue associated with this system.
The solution consists of a solar tracker that is self powered, while providing the necessary power for the TG-9 device. Therefore, the TG-9 unit is power independent (self-sustained), and to a certain extent, the unit can be remotely programmed, providing the end user with the ability to just mount the system and not worry about the unit having power issues. The tracker was designed to follow the sun from sunrise to sunset through all four seasons."
No photograph is available for this project, as it pertains to proprietary electronics devices

Green-Powered Cooking with Parabolic Solar Cooker

"In many regions across the Globe, inadequate infrastructure as well and accessible unavailable resources prevents the establishment of power grids for the supply of electrical energy. Normal mundane task done with electrical devices becomes daunting and in some cases dangerous. One basic task is the ability to cook food. In many of these regions, they do not have electrical infrastructure but they do have an abundance of Solar Energy. This project will involve the design of a Parabolic Solar Cooker that utilizes Solar Energy to provide sufficient heating for cooking as well and electrical energy for devices that will allow the user to monitor cooking temperatures and solar energy."
No photograph is available for this project due to possible patent-pending circumstances.

Solar-Powered Air Conditioning Unit for Automotive Applications

"A portable Air-Conditioning, solar powered system for automotive application was designed and tested, using a solar panel, a Peltier cooling system and a fan to keep the vehicle's interior at a lower temperature than it would be without any air-cooling/air-circulation system. For the project, flexible solar cells were used to construct a solar panel that covered an area of the front windshield, thus reducing the incident solar radiation on the dashboard. This is a common measure currently employed to minimize the heating effects of the Sun on the vehicle's interior, when the vehicle is parked during the summer days."

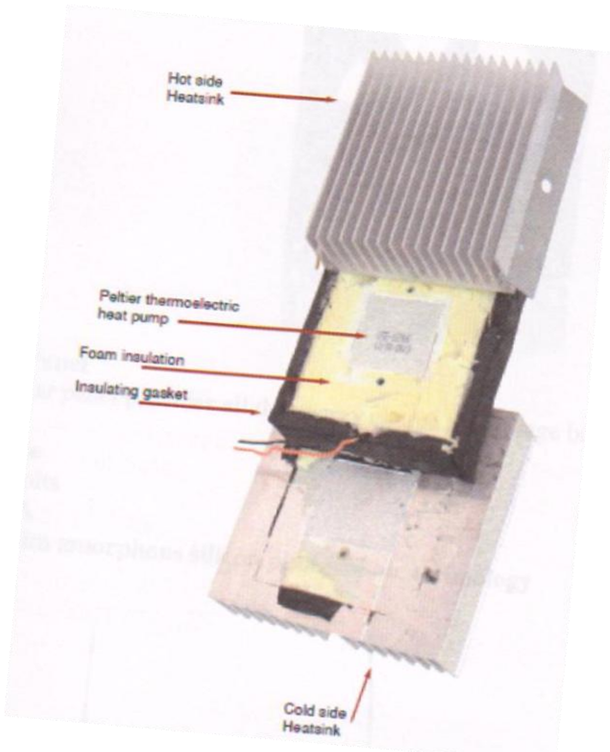

Fig. A-1: Solar-Powered Air Conditioning Unit for Automotive Applications

Solar Hat with Cooling Fan

The combination of brutal sun exposure and long hours is the culprit for heat exhaustion, heat strokes, and fatigue that outdoor works experience during the hot summer months, especially in the South and the Midwest of United States. Work long day-time shifts, makes the issue even worse. A possible and simple solution to the problem is of designing and assembling a ventilation system within a straw hat that is powered by the sun, with of-the-shelf components. The prototype has a small fan facing up implanted within the very top of the hat. On the hat's border, 24 flexible solar cells were secured and interconnected, collecting and converting energy from the sun, then it is transferred to a small battery which powers the fan at the user's discretion. Since the fan is oriented upward, the air flows from the bottom of the hat, past the ears, and finally out through the top of the hat, thus enabling a cooler air around the worker's head.

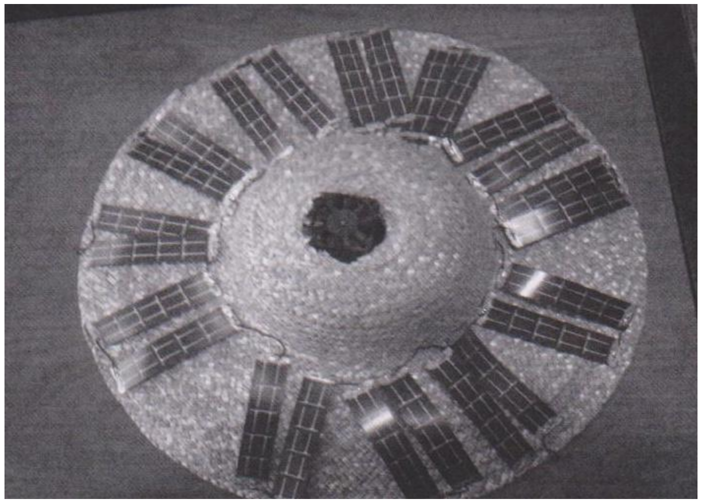

Fig. A-2: Solar Hat with Cooling Fan

Appendix B:
Selected Project Summaries for the Wind Energy Systems course (ECET 4904)

Characteristics of a Three-bladed Savonuis Wind Turbine

This project demonstrates the advantages and disadvantages of three-blade Savonius turbine, through computations of turbine's efficiency, computer simulations, and experimental validation in the wind-tunnel. It is demonstrated the Savonius three-blade turbine's inability to self-start, as well as the low wind speed range (5–8 miles/hour). Efficiencies and torque characteristic were determine experimentally, and compared to the theoretical values in the optimal wind speed range.

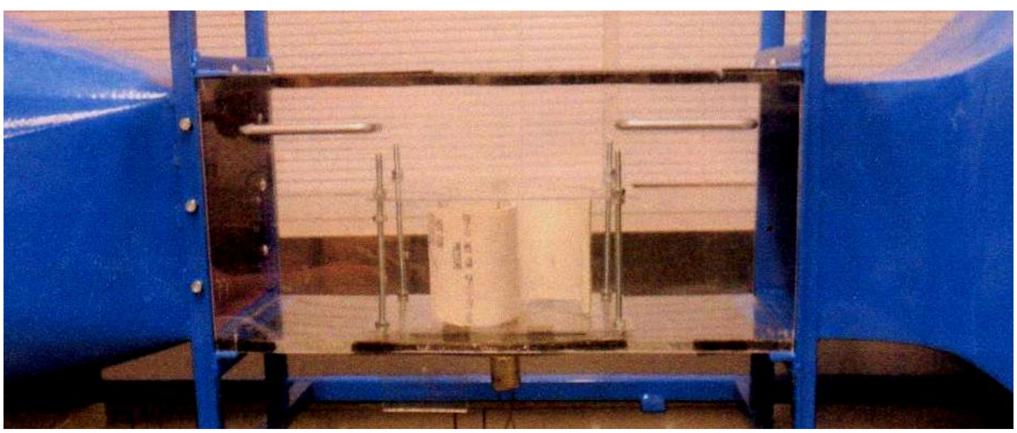

Fig. B-1: Three-bladed Savonuis Wind Turbine

Study of the Savonius Wind Turbine with Air-Gap

Savonius wind turbine with air-gap optimizes the efficiency of drag-type VAWT by improving the turbine’s aerodynamic characteristics through an air-gap between the two-blades, reducing the turbulent flow associated with operation at higher wind speeds.

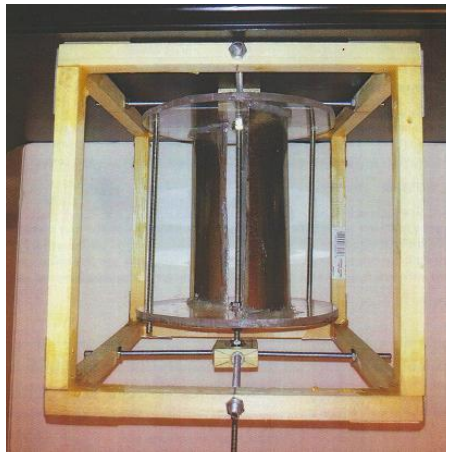

Fig. B-2: Savonius Wind Turbine with Air-Gap

Characteristics of a Dual-Stage Savonius Wind Turbine

The dual stage Savonius wind turbine, studied in this project, showed good torque characteristics, in close agreement with the computed/simulated characteristics. The 90^0 offset between the two identical two-blade rotors enabled the turbine to be self-starting, and operate on an overall positive torque. Thus the electric energy generated was of acceptable quality, with lower ripples, which were easily filtered by a parallel connected capacitor.

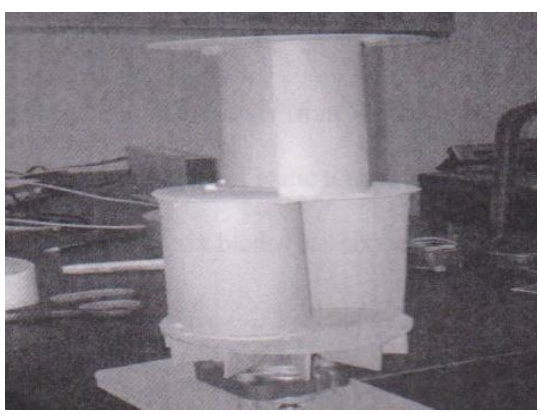

Fig. B-3: Dual-Stage Savonius Wind Turbine

Characteristics of Five-Blade Horizontal Axis Wind Turbine

Five blade Horizontal Axis Wind Turbine is a lift-type wind turbine, which converts the energy of the wind into mechanical energy (rotation of a shaft), and in turn into electric energy via a 7.5 volt generator. This generator trailed two wires from the end tail to allot assessment of the voltage. A light-bulb was connected at the generator's terminals, thus enabling current measurements. These readings were multiplied together to calculate the power output of the turbine. The wind tunnel was operated and adjusted at a range of wind speeds.

Fig. B-4: Five-Blade Horizontal Axis Wind Turbine