Development of a General Alternative-Energy Course for a Technology Program

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Abstract

Academic, business, and industrial fields have been seriously pursuing alternative energy systems advantageous to their needs. Students graduating from engineering and technology programs are involved in buying, managing and trading alternative energies during their careers as part of their job requirements. It is essential for engineering and technology students, at a minimum, to be familiar with alternative energy technologies and their applications and implementations. The proposed General Alternative Energy Course is composed of lectures, demonstrations, student inquiry, in-class problem solving, and hands-on projects. Class content includes photovoltaic systems, solar thermal systems, green buildings, fuel-cell systems, wind power, waste heat, biomass fuels, tidal power, active/passive human power, storage technologies (e.g., battery, supercapacitors), and hands-on laboratory projects. This course acquaints students with existing and potential ambient alternative energy sources, production capacities as well as energy harvesting, conversion, and storage techniques. The course concludes with a general review of how to integrate energy harvesting technologies into a system that provides a continuous and uninterrupted power stream. A detailed demonstration of course content, course materials, and hands-on course projects will be shared with academia.

Introduction

An increasing quantity of alternative energy resources presents much promise for our society. Due to this fact, the next generation of students will need more curricular support in this area, especially for those students engaged in engineering and technology programs. This is especially true as the issues of depletion of fossil fuel sources, climate change, global warming, increased electricity blackouts, and oil price variations continue to overwhelm people through the news media. So far, however, many schools from K-12 to community colleges do not have robust educational programs in these critical fields because of budget, laboratory and knowledge limitations. Alternative energy systems and sources are frequently discussed in the media and are continually in the thoughts of students from their daily life experiences and conversations. The public's general concern and interest about the environment has been increasing, and many attempts are being made to incorporate green technologies in school curricula. The number of alternative energy-related courses and programs is increasing due to the considerable demand for alternative energy sources. This demand will lead to greater competition between students in the future as they begin to seek career opportunities. Students earning engineering and technology degrees need a general knowledge of alternative energy systems, at least, to apply to their future fields.

Alternative energy-related courses are becoming an essential part of engineering and engineering/industrial technology curricula. Many schools are integrating renewable energy courses into their degree programs to support existing academic programs that expose students to energy systems and technologies [1-7]. The nature and content of renewable energy courses differ depending on the degree program of studies in various departments. For example, construction management and science programs usually adopt green building and geothermal-related classes and projects [8], engineering and technology programs adopt thermal systems, solar, wind, human power, energy-conversion systems, and biomass classes related to their curricula.

Usually, renewable energy courses provide an assessment of potential for various alternative and appropriate energy technologies to meet regional and global energy demand. They also explore conservation and end-use efficiency improvements that may allow civilization to exist in a more sustainable manner. Studies of modern energy resources, extraction techniques, conversion technologies, and end-use applications consistent with a conventional engineering and engineering/industrial technology curriculum are used as a baseline. Against this baseline, the courses introduce the physics, systems and methods of energy harvesting from non-conventional energy sources such as solar, geothermal, ocean-thermal, biomass, tidal-lunar, hydroelectric, wind, thermoelectric, human power, biomass and waves. Advantages and disadvantages of these alternative energy sources and the engineering challenges inherent in harnessing such forms of energy are covered. Evaluation and analysis of energy technology systems are taught in the context of achieving civilization's future economic and environmental goals [9-16].

The Energy Harvesting, Conversion, and Storage Systems of Alternative Energy Sources course is a general renewable energy course designed to enhance students' knowledge of renewable as well as traditional energy sources and their impacts on the environment and society. There is no prerequisite for this class so all on-campus students who have an interest in energy technologies may be reached. The basic concepts of electricity and power generation are covered at the beginning of the course to help students who do not have a background in electrical systems. Traditional energy sources include coal, hydro, nuclear, oil or natural gas; non-traditional sources include renewable energy such as wind, solar, geothermal, wave, hydrogen and bioenergy. Another goal of the course is to increase public awareness of renewable energy and renewable products through presentations, projects and discussions in the class environment. The course is the first level in a series of renewable energy-related classes that lead to an interdisciplinary minor in which students can apply their academic expertise to the area of energy and renewable energy.

Students are required to complete a series of exercises/projects and/or tests that reflect their knowledge of the stated objectives. Major points of the course are: a) understand the role of energy, energy sources and energy-use patterns in society; b) develop the basic ability to assess the relative merits and potential impacts of different energy sources; c) understand how energy conservation pertains to the management of efficient use of energy resources; d) develop basic knowledge to understand related issues of alternative energy products in the student's academic major/minor; e) develop a multidisciplinary background in alternative energy, energy conservation and efficiency, and self-sufficient products; and, f) develop an understanding of active/passive human power as an alternative energy source. The course will lead to the development of more renewable energy-related courses and eventually a degree program in the department.

Goals

The main goal of the course is to help undergraduate students develop and apply a general understanding of renewable energy-related products and their associated markets. The course is designed to be a hands-on, interdisciplinary class with an emphasis on the study of the economic, social and environmental aspects of various renewable energy sources including bio-fuels, with hands-on experiments included to offer more insight into related products. Ultimately, the program strives to educate students to understand the technical, economic, social, political and environmental aspects of various sources of energy and to become more knowledgeable citizens. A summary of program objectives is given below:

- Learn and apply applications of photovoltaic energy systems, wind energy systems, passive solar air and water heating systems, active and passive human power, hydrogen fuel-cell systems.
- Learn the role of energy, energy sources and energy usage patterns in society.
- Develop basic knowledge to understand social, economic and environmental aspects of renewable energy.
- Develop a multidisciplinary background in renewable energy, energy conservation and efficiency, and self-sufficient products.
- Develop an appreciation of how renewable energy technology works and how it is currently being used in the U.S. and around the world.
- Gain knowledge and hands-on experience in renewable energy systems.
- Learn site surveying and load analysis for renewable energy customer needs.
- Develop skills to handle hybrid renewable energy technologies.

Description

This course is a comprehensive introduction to ambient energy sources and their applications. This course will acquaint students with existing and potential ambient alternative energy sources, production capacities and energy harvesting, conversion and storage techniques. By using traditional energy generation methods and by reviewing typical energy consumption patterns, key concepts, terminology, definitions and nomenclature common to all energy systems are introduced. Design Development, Industrial Technology, Construction Management, Industrial Management and Electronics majors/minors can take this course as an elective in the technology department. In addition, any majors and minors at the college should be eligible to take this class as an elective.

Methodology

Not all engineering and industrial technology departments will be able to offer a variety of renewable energy courses due to faculty, budget, laboratory and knowledge limitations. Unless a school decides to establish a renewable energy-related program or degree, it becomes difficult for faculty to teach renewable energy-related classes in addition to the classes in the core curriculum. Since tenure-track and tenured faculty are usually allowed to teach three classes a semester, it may become an issue to offer more classes if there are not enough faculty available. If this is the case, it would be better to have at least one or two general renewable energy classes to respond to all the needs of the programs/degrees in the department. In this way, students can be exposed to general renewable energy systems and may be given the opportunity to gain further information by enrolling in a general renewable energy course in the department. Since the spring 2009 semester, students have been involved in a renewable energy course and have accomplished several projects under the supervision of a faculty member who teaches and researches renewable energy systems.

Class projects were completed in the spring, summer, and fall, 2010, semesters, and students have requested access to a general renewable energy class before they graduate. There are several students registered in a renewable energy course to accomplish several projects during the spring, 2010, semester. In addition to these projects, a comprehensive renewable energy course was developed by several faculty members to extend knowledge to all students regardless of their major or minor. Faculty are currently teaching bio-fuel systems, construction technology, construction management and procedures, electronics, design and development and industrial safety classes; they also contributed to this curriculum by suggesting related subjects to be included in a revolving *IT 469 Special Topics* class. The course content was identified after several meetings to respond to students' needs and to extend their knowledge for future projects. There were also several presentations and meetings with interested student club members to discuss and discover potential renewable energy resources for energy harvesting. The Delphi Method was used to determine researchable alternative energy subjects [17]. It is an approach which consists of a survey conducted in two or more rounds; the participants in the second round were provided with the results of the first round so that they could alter the original assessments. Students from different majors/minors shared their ideas in group meetings and discussed the ideas presented by first-round participants. If an idea was not accepted by the participants, the students were instructed to bring supportive documents to the next meeting to explain their ideas in details. Students and faculty found this method quite enlightening to discover and learn different ambient energy resources. Table 1 summarizes the potential ambient -energy-source ideas discussed by students and faculty in the last meeting of the fall, 2010, semester.

The student participants were divided into five groups of six students. In Round One, the students were instructed to propose three innovative ideas, which, to the best of their knowledge, had not been developed or researched. The groups presented and described their concepts. Each topic/idea/concept was voted on by all of the participants to determine the most achievable concept/study by the class. Table 1 presents the list of ideas identified by the participants.

Table 1. Content for New Research Related to Renewable Energy Systems

Group	Ideas	Vote Count
1	1. Amplification of electromagnetic fields 2. Photosynthetic electricity source 3. Different ethanol processes and sources	2 19 1
2	1. New battery materials 2. Geothermal cooling method	0 5
3	1. Flooring that stores kinetic energy 2. Thermoelectric generators in walls as energy source 3. Magnetic engine	10 5 4
4	1. Capture ocean and water currents as energy source	13
5	1. Ocean buoys to harvest electricity 2. Hemp as alternative organic for fuel production (ethanol) 3. Harvest wind from exhaust fans and A/C units for energy source	X* 0 20

*Group 5, Idea 1, was deemed to be the same as Group 4, Idea 1 and rejected.

Based on the counts, the top three subject ideas were selected. In Round Two, groups were reassembled to prioritize those three subject ideas according to which subject the students were most likely to pursue. The group results and consensus ranking are presented in Table 2.

Based on the results of the meeting using the Delphi Method, three ideas presented in Table 2 were considered and ranked for alternative energy research in the Industrial Technology program at Sam Houston State University. In future planning, the number of these meetings will be increased based on the interest and availability of students.

Content of the Course

Upon completion of this course, the student will able to:

- Locate and identify potential ambient alternative energy sources

Table 2. Top Three Energy Sources for Research Ranked by Meeting Groups

Subject Idea	Group					Rank
	1	2	3	4	5	
Photosynthetic electricity source	2	3	1	3	2	**3**
Capture ocean and water currents as energy source	1	2	2	2	3	**2**
Harvest wind from exhaust fans and A/C units for energy source	3	1	3	1	1	**1**

- Understand electric power generation, harvesting, conversion and storage systems
- Identify appropriate storage (e.g., battery, supercapacitors) technologies
- Learn about solar-energy systems using photovoltaic systems
- Learn to harvest energy from wind power
- Learn how to generate electrical power from biomass
- Understand hydroelectric power systems
- Learn the applications of hydrogen fuel cells
- Explore active/passive human-power sources
- Learn about geothermal energy and ground-source heat pumps
- Become knowledgeable about principles of renewable energy transportation systems
- Understand energy systems management and auditing
- Learn about energy utilization in our homes, businesses and schools
- Define relationships between renewable and non-renewable sources of energy
- Learn electric circuit design used in energy-harvesting systems
- Learn process and materials safety for alternative energy technology

Student Projects

Students are required to complete a series of projects in the class (Energy Harvesting Systems from Alternative Energy Sources) as part of the course requirements. Depending on the class size, groups are established to complete assigned projects in rotation. The instructor assigns a timeline for each group to finish their projects. If a group fails to finish the project according to the timeline, they receive partial credit for the incomplete project. Usually, a projected timeline to complete the project is sufficient for a group, because each group consists of at least three students. Students are allowed to work on their own during the weekends and under the supervision of an instructor or lab assistant during the weekdays. All of the information about the projects is provided to the other group members. Group leaders are in charge of updating the instructor about their projects; they are cautioned to ask for help if any issues arise. Groups are required to make a presentation on one of the projects they accomplish during the semester. The groups should start researching their projects in the third week of the class and finish them before finals week. A total of thirteen weeks are allowed to finish the projects. Table 3 is a sample project-assignment timeline with the list of projects.

Table 3. List of Projects Assigned to Groups

Projects & Project Timeline (2 weeks)	**Weeks/Groups**													
	3. week	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Skylight Installation	Group 1		Gr. 2		Gr. 3		Gr. 4		Gr. 5		Gr. 6		Gr. 7	
Passive Solar Air Heater Installation	Group 2		Gr. 3		Gr. 4		Gr. 5		Gr. 6		Gr. 7		Gr. 1	
Passive Solar Water Heater Installation	Group 3		Gr. 4		Gr. 5		Gr. 6		Gr. 7		Gr. 1		Gr. 2	
Wind Turbine System Installation	Group 4		Gr. 5		Gr. 6		Gr. 7		Gr. 1		Gr. 2		Gr. 3	
Photovoltaic System Installation	Group 5		Gr. 6		Gr. 7		Gr. 1		Gr. 2		Gr. 3		Gr. 4	
Hydrogen Fuel-Cell System Installation	Group 6		Gr. 7		Gr. 1		Gr. 2		Gr. 3		Gr. 4		Gr. 5	
Basic Geothermal System Installation	Group 7		Gr. 1		Gr. 2		Gr. 3		Gr. 4		Gr. 5		Gr. 6	

Laboratory Experiments

Establishing a renewable energy teaching and research laboratory involves undergraduate and graduate students, faculty, and community in learning about alternative energy and its impact in details. Hands-on renewable energy-related classes, labs, and projects promote alternative energy education at university campuses.

A fully functional laboratory delivers applied energy education workshops for local community colleges, secondary/high school science/technology teachers and students and for the general population, especially those not exposed to state-of-the-art renewable energy information. Information concerning solar, wind, passive solar water and air heating, fuel cells and human power can only be offered to small groups of students because of the limited laboratory space, current tools and components. Depending on tools and component availability, self-sufficient energy-efficient building design and construction, biomass, thermoelectric, and advance alternative energy systems may be offered at the campus. The current equipment for electronics, construction and production laboratories at Sam Houston State University are used for the renewable energy projects.

In addition, construction majors built a storage building to be used for the project as part of their class requirement. These small storage buildings are used as temporary laboratories. They are placed next to the construction laboratory and have a southern exposure for efficient sunlight. All the necessary parts for the projects were purchased with internal and external grant money and donations. No additional tools, equipment, or technological resources were necessary for students to complete the projects, since the university laboratories are well equipped and have these stock supplies. The following systems were used for the labs and hands-on projects of the course.

Skylight Installation

Tubular Skylights are energy-efficient high-performance lighting systems that are cylindrical in shape and are designed to light rooms with natural sunlight. A small, clear collector dome on the roof allows sunlight to enter into a highly reflective "light pipe" that extends from the roof level to the ceiling level. The light pipe is coated with a silver mirror-quality finish that allows the full spectrum of sunlight to be channeled and dispersed evenly into a room by means of a diffuser located in the ceiling. This project involved installation of four units of 13” tubular prismatic diffuser-type skylights on the roof of the storage building. Students learned to identify the best location on the roof to install skylights for efficient use and to increase illumination in the dark places in a house or building. They determined the length of the light pipe for installation. The picture of an installed skylight is shown in Figure 1.

Figure 1. Skylight Installation

Skylight System Components:

- 13” Tubular Skylight (Prismatic Diffuser and Pitched)
- Remote Controlled Dimmer, 13"
- Light Pipe Elbow and Extension

Passive Solar Air Heater Installation

Solar air heating systems are a supplement to regular heating systems and can dramatically reduce heating costs. Air in the building is circulated through a collector on the exterior wall, where it can gain up to thirty degrees before being vented back into the room. A 1500GS glazed secondary air heater (passive device resembling a large door) was mounted on a sunny, south-facing wall of the student-built storage buildings. A 270 CFM AC powered Combi Fan was used to circulate the air in the storage building for test purposes. The air circulation and quality of warm air were tested at different times during the day and under different weather conditions. Some of the following questions were assigned to students to learn air heating systems in detail. The passive solar heating system is shown in Figure 2.

- Does a solar air heater work at night?
- Can I mount the air collector upside down?
- What happens during the summer?
- Can I mount it horizontally?
- How long does the installation usually take?
- Where are the units manufactured?
- Will it produce heat on cloudy days?
- Is it better to use a 2 pack (solarsheat 1500G and 1500GS) or two stand alone units (2- 1500G units)?
- Do air heaters need to face true south and at a tilt angle 90 degrees to the sun?

Figure 2. Passive Solar Air Heating System

Passive Solar Air Heating System Components:

- 4", 5" 6" Combi Fan 270 CFM AC Powered
- Roof Flashing Aluminum for Shingled Roofs
- 1500GS Glazed Secondary Solar Air Heater (passive device)
- Collector Flush Mount -Tall Pads Style

Passive Solar Water Heater System Installation

Students involved in this project learn to distinguish both solar electric and solar thermal heating and have an understanding of the uses of both; they also develop a good understanding of how to identify a proper site for a solar thermal system and have resources to explore local installation options. Initially, a wheeled cart was designed using computer-design-and-drafting software tools. All major components were shown in the design. After the design of the complete system (with real dimensions), the wheeled cart was built to test the passive solar heater system in different locations. The passive solar water heating system is shown in Figure 3.

Figure 3. Passive Solar Water Heating System

Passive Solar Water Heating System Components:

- 2'X3' Sample Collector
- Standard Mount Kit for AE Series
- 100 PSI Pressure Gauge 1/4" MPT
- D5/710B PV Circulating Pump- threaded
- 35-250F Thermometer
- 10 Gal. SS DB Tank w/ Heat Exchanger
- 3/4" Cast Iron Flanges
- Taco 1/40 HP Bronze Pump, 0-6 GPM
- Eagle 2 Differential Temperature Control w/t Display
- Air Vent, 150 PSI, 1/4" MPT
- "MAXI-FLOW" Spring Check Valve, 3/4" SWT
- 3/4" 2-WAY Sweat Ball Valve
- Kyocera KS10 10W 12V Solar Panel
- AET PV Mount
- Whirlpool 15G Tank w/ Electric Element
- TACO 1/25 HP Cast Iron Pump, 0-14 GPM
- Eagle II Data Port Adapter
- 3/4" Boiler Drain
- GPM Flow Meter
- Gal Expansion Tank
- 150 PSI Pressure Relief Valve

Wind and Photovoltaic Systems Installation

Five wind turbine units (12V 200W) and fifteen solar module units (12V 65W) were purchased for student projects. All of the related parts to build a complete wind and photovoltaic energy system were also purchased to supplement the student projects. Students built a wind/solar hybrid system to control and record data to investigate the reliability of both systems. A data acquisition system was implemented to record and analyze temperature changes, solar irradiation, wind speed, power generation and consumption with load changes. The hybrid alternative energy system (solar and wind) is shown in Figure 4.

Photovoltaic and Wind System Components

Photovoltaic System:

- KC65T 65W 12V Solar Panel with J-Box
- Ground/Roof Fixed Tilt Legs
- 10-12 10A, 12V Light Controller
- BabyBox 4 Slot AC or DC Breaker Panel
- 6 Amp Din Rail Mount Breaker
- 20 Amp Din Rail Mount Breaker
- 8G24 12V, 73 AH (20HR) Sealed Gel Cell Battery
- 125W XP 125-12 12V Inverter

- 110A Fuse & Holder W/Set Screw Lug
- Vivid PAR 20 Floodlight (36 LEDs), AC/DC
- Assistant Software (PV Only)
- Solar Pathfinder™ with Case & Tripod
- LA302 DC Lightning Arrestor
- Voltage/Current DC Sensors Dual Irradiation Sensor
- Temperature Sensor

Wind Energy System:

- Anemometer (Wind Meter)
- Air Breeze Wind Turbine Land 200W 12V
- 2-Position Stop Switch for Air Turbines
- LA302 DC Lightning Arrestor
- Analog Amp Meter Kit
- BabyBox 4 Slot AC or DC Breaker Panel
- 50 Amp Din Rail Mount Breaker
- 63 Amp Din Rail Mount Breaker
- 27FT Tilt-up Tower Kit for Air Turbines
- Galvanized Augers for 27' Tower
- CB50 50A Circuit Breaker
- CBBOOT for 30A/50A Circuit Breaker
- 12V 135AH (20HR) Sealed AGM Battery
- SureSine Inverter SI-300-115
- 110A Fuse & Holder W/Set Screw Lug

Figure 4. Hybrid Solar and Wind Energy System

Hydrogen Fuel-Cell System

The solar module converts radiant energy into electrical energy to power the electrolyzer, which breaks water into its basic constituents of hydrogen and oxygen. These gases are stored in the graduated cylinders. When electrical power is required, the PEM fuel cell recombines the stored gases to form water and release heat and electricity. Students are familiarized with fundamental principles of fuel cells through solar-hydrogen fuel-cell technology. The module provided is a training unit and students are involved in a variety of laboratory experiments provided by the manufacturer. In this project, students engage in twenty to twenty five hands-on experiments for introductory and advanced environmental science, as well as demonstrate the sustainable benefits of fuel cells and hydrogen technology. Figure 5 shows a hydrogen fuel-cell training unit with a data-acquisition system.

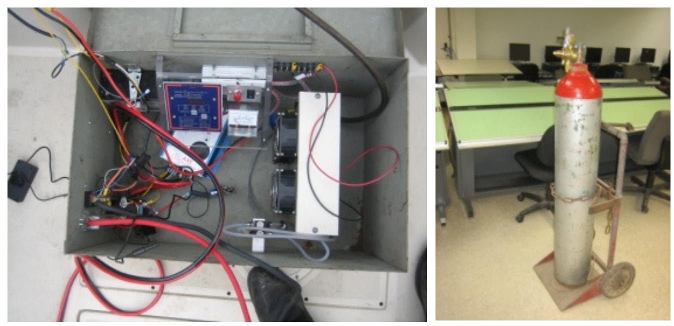

Figure 5. Hydrogen Fuel-Cell System

Human-Power Generating System

In this project, students were familiarized with the conversion of mechanical energy (through human kinetic energy) to electrical energy. Students studied low-rpm permanent-magnet DC generators, generator types, mechanical torque, human-power applications, charge controllers, battery types, measuring voltage and current, voltage rectification and power output changes with mechanical force. The instructor provided exercises to be accomplished by students and submitted for their project grade. The Human-Power Trainer is shown in Figure 6.

Human Power Generator System Components:

- Bike Power Generator
- Electromate 400, 12V Power Pack
- Power Monitor
- 10FT Connecting Cable – Diode Protected with Power Pack Connector
- Low RPM Permanent Magnet DC Generator

- 35A Power-Up Reverse Current Rectifier Bridge Assembly
- Power-Up Reverse Current Diode Assembly

Figure 6. Human Power Trainers

Solar Pathfinder

Students were divided into three groups and were provided three Solar Pathfinders, assistive software and laptops with software. A short description of the equipment, summary of the experiment and questions were provided in the experiment. A sun-path calculator was used to view the solar window for a particular location for assessing shading. Other means can be used to evaluate shading, but sun-path calculators are usually the quickest and easiest to use. The Solar Pathfinder is a popular type of sun-path calculator that consists of a latitude-specific sun-path diagram covered by a transparent dome. The dome reflects the entire sky and horizon on its surface, indicating the position and extent of shading obstructions. The sun-path diagram can be seen through the dome, illustrating the solar window. The solar window is compared to the obstruction reflections to determine the dates and times when shading occurs at the site. When a sun position is overlapped by an obstruction, the sun would appear behind the obstruction and the location would be shaded. The pictures of the solar path calculator are shown in Figure 7.

To use the Solar Pathfinder the unit was located at the proposed array site. It was leveled and oriented to true south with the built-in compass and bubble level. Looking straight down from above, the user observes reflections from the sky superimposed on the sun-path diagram and traces the outlines of any obstructions onto the diagram. Students draw shading areas in different locations and identify obstructions around the solar modules. Students are required to submit a detailed report and suggestions for the given experiment.

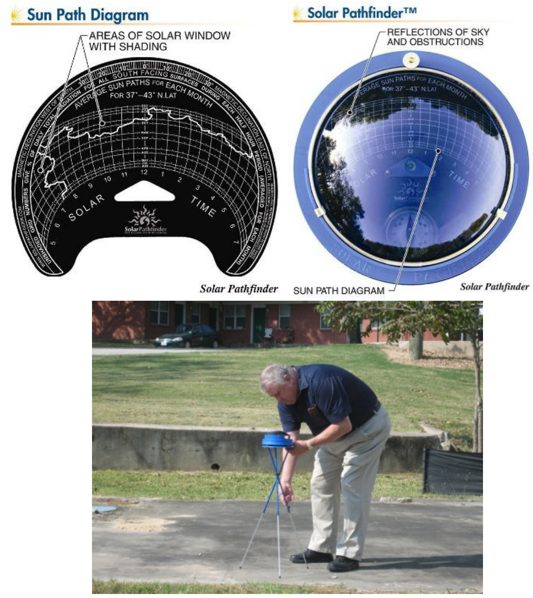

Figure 7. Solar Path Calculator System

Class Survey

To evaluate the effectiveness of the class and test the content knowledge of the students, each student was asked to complete a survey after completing the class. The outcomes are presented in this paper. Thirty-six students participated in the renewable energy class since the spring semester of 2010. The authors believe the data gathered from the student-participation questionnaire indicate that this experimental class promotes alternative energy systems. The results indicate that the class is promising and should be introduced to more students, regardless of major. Survey results are summarized in Figure 8. Fifteen multiple-choice (select 1-5 type) and four questions for additional comments comprised the survey and are summarized in Appendix A.

Conclusion

In this paper, the *IT 469 Energy Harvesting Systems from Alternative Energy Sources* course taught in the Industrial Technology Program at Sam Houston State University is summarized. Student feedback was very

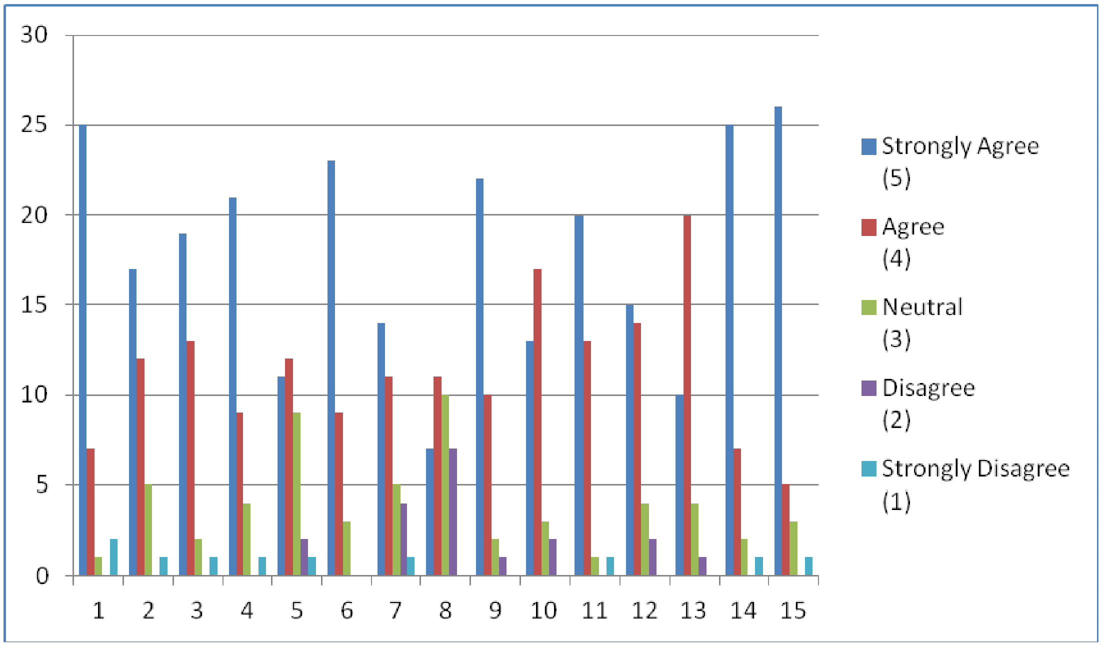

Figure 8. Student Survey Results

positive and critical comments were made to improve the class.

Most of the students suggested there be several field trips, when time permits to see industrial working systems. The main themes covered in the course are the needs, concepts, operation principles, modeling issues and simulations of solar, wind, passive solar air/water heating, human power, geothermal, hydrogen fuel-cell systems and their techniques. This class did not cover all potential energy sources due to time and equipment limitations. Students showing an interest, and who wanted to accomplish energy projects, are encouraged to enroll in a directed (independent) study course. This class is offered as an elective course and is not in the current catalog, but was already a full class by the end of the first day of class registration. Several students attempted to register for this class but were not allowed to because of equipment and laboratory limitations. Several faculty members who are currently on the curriculum development committee desire to increase the number of energy-related courses.

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Biographies

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NEDOM C. MUNS is a Professor of Industrial Technology at Sam Houston state University. His primary teaching area is Construction Management, Vocational Teacher Education, and Design & Development.

Appendix A. Survey Questions

<table>
<tr><td colspan="3">Note: This survey is prepared to measure effectiveness of the training unit (mini-lab) in the hands-on learning process of Photovoltaic and Wind Systems. Please place a “X” to corresponding and preferred section.
Questions</td></tr>
<tr><td>1. Have you found the course useful to improve your knowledge on renewable energy applications?</td><td>2. Have you found the course and term project useful to improve your knowledge on energy efficiency and efforts on reduction of carbon foot print (CO_2)?</td><td>3. Do you think solar and wind power applications will help you as a student to understand renewable energy systems better?</td></tr>
<tr><td>4. Do you think renewable energy would be a good tool to promote science and technology majors in college?</td><td>5. Would you be interested in enrolling in a Technology curriculum course entitled Applied Renewable Energy promoting Math, Science, and Engineering?</td><td>6. Overall quality of instruction was appropriate and useful for this class.</td></tr>
<tr><td>7. I am interested in future classes, workshops, and summer research activities in these or similar subject courses at SHSU.</td><td>8. Before undertaking the Photovoltaic and Wind Power System Experiments, I felt comfortable with the concepts related to photovoltaic power.</td><td>9. The Introduction to the Photovoltaic and Wind Power System Experiments given by the instructor was useful in understanding the operation of photovoltaic and wind power systems.</td></tr>
<tr><td>10. The Laboratory Description document was useful in understanding the experimental procedure and data reduction.</td><td>11. After completing the Photovoltaic and Wind Power System Experiments and Lab Reports, I have a better understanding of the operation of photovoltaic and wind power systems.</td><td>12. After completing the Photovoltaic and Wind Power System Experiments and Lab Reports, I have a better understanding of the performance (power output and efficiency) of static and tracking photovoltaic and wind power systems.</td></tr>
<tr><td>13. The PV and Wind Power System Experiments increased my interest in photovoltaic and wind power systems.</td><td>14. I believe that alternative or renewable energy is important for the future.</td><td>15. This course has increased my understanding of alternative or renewable energy sources.</td></tr>
<tr><td colspan="3">Comments: “How could the PV and Wind Power System Experiments and Course be further improved to enhance the learning experience?”</td></tr>
<tr><td colspan="3">Question: If you are given a chance to find a unique (undiscovered) renewable energy source what would be a first, a second, and a third source you would like to implement? For example, energy generation from an AC condenser outside of a building (Cost and application is not considered just list a source to generate electricity).</td></tr>
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