Energy System Design: A Look at Renewable Energy
Faculty Project Description

The Hands-On Project: Assignment Description

Design Project:

Students are asked to design, construct, test, and evaluate a device that simulates a system for harnessing, storing, transporting, converting, and utilizing renewable energy from a water, wind, or solar source.

Guidelines:

Students are offered three possibilities for sources of renewable energy: water at an approximate flow rate of 0.5 liters per second; solar energy provided by a 90-watt flood light; and wind energy provided by a box fan with settings of 166 watts, 117 watts, or 87 watts. After setup of the apparatus is complete, students are given up to two hours to collect energy. (For classes that operate on a tighter schedule, this timeframe can be decreased to a 45-60 minute range and still yield successful results.) After each group has concluded its collection time, they are required to transport the energy to a designated area to perform the utilization aspect of the project. The overall goal of the project is to light a 1 cell AAA Maglite® light bulb (0.4 W) for a minimum of 15 seconds.

Each team is confined to a budget of $100.00, which must account for any part of the design outside of those which provide the “source.” The team must submit a detailed list of costs incurred for review by the instructor and determination of the cost index (see Grading). Furthermore, the most important facet of this project regards safety. Safe practices must be adhered to during the construction phase, collection phase, transporting phase, or testing phase of the project.

Project Milestones

Prior to the start of the design project, the students are required to complete a team application (see Faculty Project Description Supplemental Materials for Team Application example) and the instructor divides the class into teams of 4-6 students; and then the class completes a BESTEAMS module related to personal effectiveness and increasing self awareness. BESTEAMS (Building Engineering Student Team Effectiveness And Management Systems), Curriculum Guide for Faculty has been developed by Drs. Linda Schmidt, Janet Schmidt, Paige Smith, David Bigio and Jeanne Bayer Contardo, ISBN 0-9723567-4-6. The teams then embark on the engineering design process to complete their renewable energy system. Specific milestones include identify and define the problem, research and brainstorm ideas, select the best solution (simulation), model the solution (build the prototype), evaluate the solution (testing) and communicate the solution (both written and oral). Each of these milestones is required in a timely fashion over the course of the design project.

Reporting:

In addition to constructing their device, each team must also provide a mathematical basis for its operation. It is the responsibility of each team to research the necessary equations to determine the energy used during collection, power output from the system, useful work output during testing, and overall system efficiency. The overarching principles are presented in the background lecture.

Each team of students is required to maintain a design notebook which entails each of the team meetings. Within the notebook should include preliminary research to determine design ideas, a log to show the evolution of the final design apparatus utilized by the team, results from preliminary and final testing, as well as all required mathematical calculations for the project. The design notebook should be submitted to the instructor at the conclusion of the activity.

At the conclusion of the project, each team is required to compose a formal written report entailing the background information (research) of the project (including its importance), the details of and reasons for their respective design, results and conclusions from testing, mathematical calculations, and suggestions for future teams. In addition, this report should be summarized in a brief oral presentation. (Either or both of these items are optional based on allowed class-time).

Grading:

The performance of the design can be judged based on the following formula:

(Power Generated) x (Overall System Efficiency) x (Device Cost Index)

The power generated refers to the electrical output measured initially when the utilization test is performed. It is determined by voltage and current readings taken at the start of the utilization testing. The overall system efficiency refers to the useful work output divided by the energy input during collection. Useful work output is determined based on how long the light bulb remains illuminated and energy input is the amount of energy spent by the chosen source during collection. The device cost index simply means dividing the minimum cost of all participating teams which meet the minimum design criteria by the device cost of the team being tested. This rubric provides an insight into the success of each design and is recommended for team “bragging rights” purposes.

The final grading of the project is weighted more towards the demonstration of the team exhibiting knowledge of relevant material and accounting for their success/shortcomings during their design. The suggested grading rubric is 50% report, 25% presentation, 10% design notebook, 10% peer evaluations, and 5% “bragging rights.” (Each instructor certainly may vary this based on their preferences.) A detailed grading rubric for the written report, presentation and peer reviews have been included in the Faculty Project Description Supplemental Materials.

The Hands-On Project: Setting Up and Getting Started

This project has been created as a design activity for young engineering students in order to promote utilization of the engineering method intertwined with creativity of design. Since the project offers several options for completing the desired assignment, there is no specific “kit” of supplies that will apply to each group of students. There are, however, several things which the instructor should prepare for prior to participating in this activity.

This project is designed in a manner which allows it to be applied as an overarching activity for a semester or year-long course or as an in-class exercise to be completed in the short term. For the option of using this work as an overarching design project, instructors can determine the amount of classroom time they desire to allot for the activity in conjunction with students expected to work outside of the classroom. When this project was used at the collegiate level, only two 50 minute lectures were devoted to the discussion of the underlying engineering design, math and science principles needed for the design solution. The entire design and construction of the energy system was done outside of class time. Once the designs were completed, two 2-hour discussion sessions were used for the testing of the design projects and the oral presentations (for each discussion session of 30 students).

In addition several hands-on activities/demonstrations have been developed which help demonstrate the underlying concepts of this design project. Examples include: a hand cranked generator which is used to light an incandescent and/or a LED; creating an electric motor with a battery, wire, magnets and paper cup; a shaker flashlight made from poster board, magnets, empty film canisters, wire and LED; a simple wind mill to demonstrate how wind energy can be harnessed and converted to electrical energy; and how hydro power and solar panels can be used to lift a weight and calculate power output. Details of these activities can be found the Supplemental Hands On Activities PowerPoint Slides. These activities, along with the design project provide students with a better understanding of how much energy is needed to light a light bulb, how renewable energy can be harnessed, stored and converted into electrical energy, and how the overall system efficiency is dependent of the efficiency of each of the components of the system.

Instructors are expected to be responsible for the equipment used for the “sources,” as well as for testing the systems. For the sources, instructors will want to acquire two or three 90-watt flood lights with holder ($8 each flood light and holder), two or three box fans ($50 each), a hose (for use with a faucet as the hydro option), a liquid measuring bucket ($8 for the hose and bucket), and one stopwatch per team ($5 each). Testing equipment includes the purchase of at least two multi-meters ($40 each), some alligator clips with leads, and three or four 1-cell AAA MagLite® bulbs ($10 for clips and bulbs). It is also recommended for the instructor to provide a 0.95-watt light bulb and holder for projects that are more successful ($3). It has been our experience, that most of the teams will choose to store (and transport) their energy in a rechargeable battery. Instructors may opt to provide several of these batteries that have been drained for the purposes of ensuring that the students begin the activity with no charge in their battery (tester and battery ($12). It is also possible to leave this responsibility to each group and simply require the demonstration of a lack of charge prior to the start of energy collection.

In addition to providing the above equipment, instructors may wish to provide several items that can be used for creation of the projects to allow for simpler access. It is not necessary for these items to be provided – in fact, the project design actually encourages students to be willing to go beyond any provided items in creation of their energy system - but time/cost constraints on the students may make this option more applicable. The list below features several items which were provided by instructors during two of the three project trials and the cost associated with providing each item. For the third trial, no list was distributed to students – but they were informed that some items were available to borrow. This was done in an attempt to vary the projects and instill creativity; and indeed the design solutions in third trial were more creative.

Part(s)	Specifications	Cost
0.5V Solar Cells	100 mA	$3.50
	200 mA	$4.50
	300 mA	$6.00
1.5V Solar Cells	50 mA	$9.00
	100 mA	$10.00
	200 mA	$13.50
3.0V Solar Cells	20 mA	$11.00
	100 mA	$16.00
DC Motors	1.5-3 V	$2.29
	1-6 V	$2.40
Rechargeable Batteries	AA NiCd/NiMh	$5.00
Battery holder	Holds 1 AA battery	$0.99

In addition to these items, students are permitted and encouraged to “scavenge” for items at home and/or for purchase in stores/online. Any “used” items that students apply to their design are to be assigned a cost as if the item had been purchased new to reproduce their system.

Teams were not bound by this list in any way. If the team desired to purchase similar items at costs varying from the list, they are allowed to do so. In addition, students were not restricted to the use of AA batteries, but the use of higher power batteries may cause damage to the MagLite® bulb, requiring the instructor to use a light bulb with higher wattage capability during testing. Students should provide proof (included in their design notebook) of the cost for any items that they acquire on their own.

It is at the instructor’s discretion what assistance he/she will provide for the students to complete this project. The activity is designed for the students to complete all design, development, construction, and operation on their own. The instructor may, however, choose to provide additional lectures, design ideas or special topic assistance based on the specific needs of a given class.

Observed Tradeoffs

This design project has been used with several hundred students at both the high school and collegiate level. All three sources of renewable energy have resulted in successful designs; and each has resulted in winning the “bragging rights” competition. The underlying science and engineering principles for successful calculations can be found the Background Lecture. Key design features included efficient means for energy collection and conversion and using rechargeable batteries for energy storage. Several successful design utilized parts from a shaker flash light to charge the batters. Most of the designs were aided by the use of diodes. The light bulb was illuminated up to 8 hours by energy system designs which utilized converted car parts for energy capture and conversion.

Goals of the Project

This project originated because of the desire to expose young potential engineers to the important issues surrounding renewable energy in today’s society while grabbing their attention by demonstrating the issue via a fun, hands-on exercise. The entire learning module is based on inquiry based learning, which allows students to accrue knowledge on the topic(s) in a participation-based environment, sparking interest and enjoyment and leading to a greater interest in science and engineering for the future.

The energy systems activity will teach the students how to work together as a team and utilize the engineering design process to properly design and implement a project that has real world value. Within the assignment, students will gain insight into the types of renewable energy that are becoming prevalent in the world today, problems regarding energy which society is facing in the not-so-distant future , and the difficulty of being efficient within a renewable energy system. Students will also be exposed to trade-off scenarios based on the type of energy they choose, cost increase versus energy output and efficiency, among other encounters of the design process. Overall, this project provides a solid introduction to engineering design and revolves around a current issue of great importance.