AC 2010-1670: ALTERNATIVE ENERGY, AN INTRODUCTION FOR ENGINEERS

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Alternative Energy, an Introduction for Engineers

Abstract

The purpose of this course is to give undergraduate engineering students opportunity to explore multiple types of alternative energy sources and reflect on the implications of the implementation of a particular energy source. Lifecycle planning, engineering and management of particular forms of alternative energy sources such as wind turbines, photovoltaic, geothermal along with many lesser known sources were researched by the students. The format of the course was structured such that each student had a unique topic area to research and present to the class the basics of a given energy source along with current trends, challenges and opportunities. The key "big idea" was to empower the students to critically review non-traditional energy sources (i.e. non-fossil fuels) and develop a level of comfort in addressing not only the hard technical implications related to alternative energy but to also encompass the "soft" side of society's opinions, global impact, legal aspects (codes, zoning and laws), environmental concerns and construction difficulties.

The second "big idea" was that as each student became more knowledgeable in the area they were researching they would present related technical, societal and legal issues for discussion with the class promoting a dialog and better understanding of such for all. Aside from the more mainstream alternative energy sources, students investigated wave and tidal systems, Lunar Helium-3, and magnetic power sources. While some sources are currently lacking in practical application, the students were encouraged to "think outside the box" while keeping up critical thinking to identify areas for opportunity and challenges to be overcome.

The intent of the course was to use aspects of the "Understanding by Design" philosophy in the course development and to support the ABET Engineering Program Outcomes by giving students an opportunity for active learning while emphasizing the importance of self learning and continuing education. Focus was also placed on ensuring that each student gained additional experience in communication and participation in discussion with relevant inquiry.

1. Introduction

Alternative energy (AE) has continued to be a hot-button topic for a number of years. Many colleges and universities have consequently introduced courses on this topic, having a variety of formats: with[1,2] or without[3] experimental laboratories, project based[4], or based on a multidisciplinary approach[5]. One issue when covering such a broad field is that many students never get a complete picture on all that is involved or related to a given technology. To that end, with the support of our institution's curriculum committee, it was decided to develop and offer an overview or introductory class for Mechanical Engineering students. The course must be in support of the Program Outcomes adopted by our program (included in the Appendix) based on the ABET criteria for the Bachelor of Science in Mechanical Engineering[6] (BSME) and since our institution, under the Higher Learning Commission (HLC), is utilizing Academic Quality Improvement Program (AQIP) as part of its institutional accreditation, Understanding by Design (UbD) techniques were incorporated in the course development.

Development of a class using UbD[7] philosophy is very similar to the manner in which engineers approach problems to develop viable solutions. Goal(s) are established for the class through a process similar in concept to identifying criteria and constraints, exterior and interior, relating to the description of a problem. The goals focus on what the student will, at the end of the class, be able to understand, know and able to perform. Assessment and evidence of completion of the goal is provided through Performance Tasks and other, perhaps traditional, evidence (i.e. quizzes tests, homework, etc.)

This paper describes the development and first run of the "Alternative Energy, an Introduction for Engineers" course, developed by the authors as a technical elective course for undergraduate Mechanical Engineering students. The class is presented in the format of a 4-credit (four contact hours per week) 10-week class. As this is a broad overview of the industry and issues relative to the topic, the only prerequisite is Dean's permission. This is to ensure that students have sufficient technical background and that placement of the material is in the latter portion of the student's educational path.

Baker College system utilizes the quarter schedule, classes are offered in 10-week quarters in Fall, Winter, Spring, and Summer. All Mechanical Engineering courses are 4 credits per 10-weeks. For courses without a laboratory component there are 40 contact-hours of instruction per quarter, thus, three quarter classes are roughly equivalent to the number of class hours of two 3 credit courses over two semesters.

2. Topics and Course Requirements

The course description as initially run is as follows: "Alternative energy methodology will be discussed and analyzed based on practicality, efficiency and overall acceptance. Conservation, recycling and resources will be investigated along with methods to utilize renewable energy generation. Limitations, legal issues, appropriate application and the implementation process will be studied, and theoretical plans with timelines, costs and ROI will be investigated."

The class format is similar to a traditional lecture based class but with considerable expectation of student research both in and outside of class time. A guest lecture presentation by a local expert in wind turbine technology and implementation was also part of the class. A field trip to a "local" wind turbine farm with demonstration of Laker Schools program of AE and outreach being done by them supported the class's appreciation of opportunities. The class was delivered to minimize the amount of printing (leading by action) so all communication between students and the instructor outside class was via email and student work was delivered to the instructor by the same manner. Blackboard was considered but discussion with the class supported a reduced requirement of logins and different media requirements.

In keeping with the UbD framework, the Student Learning Outcomes (SLOs) were drafted as "big ideas" and formatted to support the Program Outcomes for the BSME and also promote the Program Educational Objectives of our program, included in the Appendix. The SLOs were:

1. Through analysis and critical thinking, the student will become "content competent" in at least one area or type of alternative energy evaluation, analysis, planning, and at least theoretical implementation of said area.

2. By the completion of the course the student will be cognizant of a majority of the aspects and areas of concern relating to different types of alternative energy production.
3. The student will be able to present and lead analytical discussion in at least one focus area of alternative energy.

These SLOs are particularly relevant to ABET Program Outcomes (c), (f), (g), (h), and (i), defined for the Mechanical Engineering program as described in the requirements for Engineering Accreditation Criteria (EAC)[6]. One of the basic underpinnings of the class for students to become aware of is how much they don't know about a topic. Secondly, the students discovered how they can become well versed on a topic with structured research and open discussion. This is critical to the ability of maintaining life-long learning coupled with communication skills, both receiving and disseminating information. Lastly, the focus on contemporary issues and current news about non-fossil fuel energy sources helps students realize that there are emotional, legal, societal, environmental and other concerns that impact the viability of a particular solution. From this beginning the 10,000 foot view is described.

Each student was required to review a current alternative energy related news item or periodical story and submit a synopsis on a weekly basis. Each would also be discussed in the following class period among the class to identify the various points of view and impact on engineering aspects of implementation of such.

The following topic areas were covered in the class with extensive discourse on some areas:

- Conservation – with efficiency and reduction of dependency as the overriding preference instead of merely reduction of services.
- "Mainstream" AE areas – power generation methods (i.e. wind, solar, fuels, nuclear, "clean" coal, biomass, geothermal); heating methods (i.e. solar, geothermal, pellet/wood); transportation (i.e. bio-fuels, electric, compressed air, fuel cell).
- Financial aspects – costs associated with design and implementation, ROI, feasibility, real and life-cycle costs.
- Laws and Regulations – legal aspects, federal and local requirements, zoning ordinances etc.
- Safety and Security – review the ramifications of centralized vs. distributed systems, impact on people and industry.
- Renewable energy sources – limitations to potential sources.
- Scheduling and planning – investigate implementation time frames and life time of a particular installation.
- Efficiency – how much energy is used and how much energy produced is actually usable.
- Societal aspects – NIMBY & BANANA (defined as Not In My Back Yard, and Build Absolutely Nothing Anywhere Near Anyone/Anything) and related quality of life issues.

- History and future – what has been tried, what worked, what might be used in the future.
- Transmissibility and Storage – is an AE system 'use at once' or how may the energy be stored and/or transported for use at a later time or different place.
- 3rd World vs. 1st World – what are the concerns with expanding energy use by those not currently using the majority of resources generated and what should be considered when expanding usage across the globe; should the majority of energy usage be confined to industrialized nations.
- Environmental impacts of AE – how has expansion affected life and natural resources and mitigation schemes to lessen future impact.
- Job opportunities for working in the AE field[8]

The topic areas are not ordered in any way to importance or position of presentation but rather are all discussed early on during the term and focus brought back to each as appropriate when discussing a particular AE concern, or to point out the interaction between topics when considering points of view of the public.

A major final presentation was required of each student with 45 minutes set aside for each. The students covered their particular research topic before the class and discussion time was allowed for questions and comments. The scope of the supporting paper and outline for the presentation included the following:

- Type of AE researched (What).
- Applications of the AE (Why).
- Area of application – residential/personal, commercial or infrastructure (Who).
- Plan of development or steps to complete (How and when).
- Return on Investment (How Much).
- Acceptability by community/society (Where).
- Engineering Issues – sizing, siting, suitability, safety, security, storability, sustainability and standards, the eight "S's" of AE engineering and application.

Stress was put on realistic projects vs. wishful thinking, being able to balance requirements against concerns with keeping environmental and societal concerns alleviated as best possible. However, AE topics were not limited to the mainstream. Students were encouraged to think beyond what is actively being built and research areas which might be of great potential given sufficient advancement in technology and manufacturing processes. Analysis of requirements and constraints was practiced with discussion of how laws, zoning ordinances, and public opinion can shape AE development without regard to actual engineering needs or limitations.

3. Format and flow

The course was presented as a cooperative effort between the students and the instructor. Expectations and guidelines were discussed and agreed to by both parties during the introduction phase of the class. Discussion of personal experiences relating to AE and observations of implementations projects were shared. No textbook was required as there currently exists nothing covering the breadth of the topic as described in previous sections. Use of the internet for resources is encouraged and, in particular, reference to AE blogs and technology articles via links were provided on a regular basis by the instructor[9, 10].

The students each emailed the source of a story and a summary on a weekly basis as a homework assignment. During class time they were expected to share insights gained from their weekly research with the class. The topics selected by this first class were as follows: Nano Generators, Wind, Solar PV, Biomass (Pellet/Fuel), Hydro, Fuel Cells, Fusion and Waste Biomass. This was partly in an effort to keep research efforts moving forward as an assist for the student, but also allowed for current events in the news to be discussed and shared with the class.

One of the exercises worked by the class was reviewing a simple monthly electric bill (supplied by the instructor.) The problem was identified as to replace the grid provided electricity with a Solar Photo Voltaic (PV) system suitable for the location. The first step was to estimate the size of PV array that would be necessary for the given kWh used. The students found, via web search, mapping for the average number of hours of sunlight per day for the geographic area in which the dwelling is located. Estimates based on manufacturer's data of solar cell output were calculated to give a minimum footprint size that would be required for the array itself. It was useful to describe to the students the size array needed as it related to the size of the classroom we were sitting. (Ceiling tiles are a great way to measure room size.) Size estimates and a physical manifestation is useful for the students to relate to a unit's size in comparison to a house or a given lot size. Rule of thumb costs for solar cells were applied to get a rough baseline cost for a system.

Knowing a base cost, utilizing the electric bill provided, a rough ROI was calculated including the assumption (2009 U.S. federal tax law) of a 30% tax write-off if installed by the end of 2009. Determination for the number of years given a constant cost per kWh of electricity was then compared to the estimated life time of the solar panels themselves. Part of the discussion at this point referenced the climatic conditions of the Michigan area. While ambient temperatures are taken into account in manufacturer's data for a unit's energy output, students are usually not cognizant of the effects. Additionally, severe weather discussion focused on strong winds in the area and the possibility of tornados having a detrimental effect on the installation depending on the supporting structure and physical positioning.

With discussion focused on installation, the impact of siting, the location for the AE construct itself, was expanded upon. Ramifications of how trees (including tree types, maximum size and rate of growth), site facing (direction, angle and elevation), and supporting structural features would affect this particular installation were discussed. Property lines, boundaries, and neighbors opinions were also taken into consideration. The site located is not in an area where zoning would currently have an impact but discussion on how that would be approached was brought up.

A hands-on laboratory exercise using a small solar panel and a standard shop flood light showed the power output of a mono-crystalline photo voltaic cell. The voltage and current were measured using a digital multi-meter so that the power output could be calculated. Using the physical size of the cell as a base, total PV array size was estimated. The construction of supporting framing and ancillary structure and wiring was not developed since the point was to provide the students with a mental picture of estimated size requirements instead of detailed construction.

4. Assessment

Following the pro-forma discussion at the beginning of class relating to school policies, grading, responsibilities, etc., a pre-assessment in the form of a discussion was lead to develop a sense of level of understanding for the students in the class. The list of aspects, outlined above, was reviewed and direct student feedback was solicited to gage level of awareness. Open ended questions were used to measure student understanding such as:

- When was federal law enacted allowing individuals to put excess generated power back on the electrical grid?
- What are the local zoning ordinances in your area relative to AE installations?
- What are the major AE areas and which players are the biggest in those areas?
- What physical conditions are necessary for successful implementation of a residential wind turbine (e.g. height, wind, location)?
- What has been done to reduce dependency on fossil fuels and encourage recycling in your home, city, state?

Much of the information questions were generated from current event items and publications. The purpose of the exercise is to draw awareness of the topic back to the big picture and what impact non-engineering aspects have on the design and implementation of AE solutions. Secondary purpose was to impress upon soon-to-be engineers that public opinion does matter and that they will need to be cognizant of politics, topical news and a general sense of what is actually going on in the world around them, i.e. read the news on a regular basis and participate in the ongoing discussions.

The majority of the ten week class was spent discussing different aspects as outlined in the topics above. For grading purposes (since each completer must have a course grade assigned) grades were based on weekly synopsis submission, via email, of a news item relating to alternative energy. During class starting the third week, discussion was lead by each student as to their progress of research of the specific area of interest. The major portion of final grades was based on the student's research paper and presentation. Student research submissions were to adhere to typical paper formats with the inclusion of sections for societal impact, economic concerns and cost ramifications. The author's policy expressed to the class is the express expectation of correct format including, but not limited to, proper spelling, grammar and punctuation. This is to stress the need for accurate and precise communication. Critique of each student's oral presentation took place with class participation. Focus of this was on visual impact to the audience, pronunciation and enunciation along with ability to field questions presented.

Class participation was a portion of grading of the students and 3% of each student's grade was based on attendance at two professional society meetings outside class time and political involvement. These could be from the on-campus ASME Student chapter meetings, SAE Senior Section meetings, both held on campus, or other professional presentations. The political involvement portion could be satisfied either by voting in their jurisdiction or, if no elections were held during the term, by submission of an essay on the importance of political participation by engineers as a way of supporting their profession. This portion of the grade was an all-or-nothing reward.

At the conclusion of the class, students were asked to rate their awareness of the broad areas relating to AE aside from purely technical and engineering criteria on a scale one to ten. Student response average was 8.6 leaning strongly toward their personal belief that the class provided them with much more knowledge and understanding about alternative energy than before the class.

5. Conclusions

The class was a success insofar as covering a broad range of the AE requirements which have influence on progress towards reduction of dependence on fossil-fuel energy generation. Presentations submitted by the students were thoughtfully researched and each student was able to take away a raised awareness of the interconnected nature of a systematic approach to implementation of alternative energy power production.

The case study discussion of transferring from grid electric to Solar PV system was an excellent way to start students thinking about ramifications of alternative energy from totally off grid to grid linked systems. It opened the door to discussion of fees imposed by energy suppliers ostensibly for moves to less dependence on fossil fuels and the road blocks power suppliers have imposed since the 1978 federal law allowing individuals to link their power generation to the grid. The state of Michigan has only recently had laws enacted to allow for net-metering.

Future offerings of this class will include rubrics to reduce subjective grading of weekly synopsis submissions as well as for project submissions and presentation evaluations. An objective assessment tool specifically for evaluation of the research topic and presentation is planned before the next offering of this class.

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Appendix. Program Educational Objectives and Program Outcomes of the Bachelor of Science in Mechanical Engineering Program

Program Educational Objectives

1) To produce graduates who demonstrate professional competence in engineering practice in local and global industry environments, or in related careers in government or academia.

2) To produce graduates who exhibit effective communication, team work, and readiness for leadership while acting ethically and professionally.

3) To produce graduates who maintain awareness of societal and contemporary issues and fulfill community and society's needs.

4) To produce graduates who actively engage in life-long learning, by completing professional development/training courses and workshops, acquiring engineering certification, or pursuing and completing an advanced degree.

Program Outcomes

The graduate will have:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
(l) an ability to apply principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations) to model, analyze, design, and realize physical systems, components, or processes
(m) an ability to work professionally in both thermal and mechanical systems areas