AC 2011-2012: BUILDING EXPERTISE ON ENERGY SUSTAINABILITY (BEES) - AN INTEGRATIVE MODEL TO INCREASE RESEARCH AND EDUCATION IN ENERGY SUSTAINABILITY

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Building Expertise on Energy Sustainability (BEES) An Integrative Model to Increase Research and Education in Energy Sustainability

Abstract

The United States is currently facing a critical challenge to transform our current fossil fuel-based energy economy to a stable and sustainable energy economy. This transformation must be achieved in a timely manner to increase U.S. energy independence, enhance environmental stewardship and reduce energy and carbon intensity, and generate continued economic growth. (National Science Foundation 2009, *Building a Sustainable Energy Future*). Moreover, the Obama administration has placed a high priority on accelerating the transition to a *"clean energy, green economy"* in the U.S, a priority that makes the vital connections between climate change, economic stimulus, energy security, and job training. The missing link in this interconnected system is the critical role that higher education must play in helping to make the clean energy, green economy a reality.

This paper describes a model called "***Building Expertise on Energy Sustainability (BEES)***" to increase research and education in Renewable Energy Systems within an existing industrial engineering program. The *BEES* model is a comprehensive approach composed of four key components, which are: 1) **Education**, 2) **Research**, 3) **Outreach**, and 4) **Connection.** Each component consists of a set of structured activities to help increase education and research in renewable energy systems.

For the ***education*** component, a systems approach for curriculum development is used. The new curriculum on *Energy Sustainability* provides an overview of the major energy flows and the issues associated with production and end-use. Major current sources of energy include fossil fuel, hydroelectric, nuclear power, and wind energy. In the ***research*** component, a *Pair-2-learn (PAL) model* is used to form teams of undergraduate and graduate students to work in specific research projects. In the ***outreach*** component, different lesson plans are developed for high school teachers participating in the UTeach Miners program. The products provided under this component are complete handouts including (*i*) student activities, (*ii*) classroom modules, extensions, and homeworks and, (*iii*) teachers handouts in the Renewable Energy Systems and Natural Resources area. The main goal in the ***connection*** component is to build stronger connections among different institutions, therefore guest speakers are invited to come to our University with the objective of providing a seminar, reviewing the curricula developed, share all material developed and explore ways for future collaborations. Formative and summative evaluations are used to assess the objectives of the *BEES* model.

1. Introduction

The United States is currently facing a critical challenge to transform our current fossil fuel-based energy economy to a stable and sustainable energy economy. This transformation must be achieved in a timely manner to increase U.S. energy independence, enhance environmental stewardship and reduce energy and carbon intensity [14]. The National Science Board (NSB) offered key findings to the U.S. Government on building a sustainable energy future. One of the recommendations (*Finding 4*) is related to the investment on ***Energy Education and Workforce***.

As indicated by the NSB, the human capital development in the sustainable energy sector is vital. Moreover, the Obama administration has placed a high priority on accelerating the transition to a *"clean energy, green economy"*, a priority that makes the vital connections between climate change, economic stimulus, energy security, and job training. The missing link in this interconnected system is the critical role that higher education must play in helping to make the clean energy, green economy a reality [1].

Higher education has a critical role to play. Colleges and universities can — and must — help students understand the complex connections and interdependencies between the environment, energy sources, and the economy — connections that underpin the concept of a clean energy, green economy [1]. Unfortunately, there is a serious lack of renewable energy and natural resources curricula throughout the nation [16, 19]. Goswami discussed the current need and substantial opportunities to bolster renewable energy education in the U.S. [3]. Moreover, ***most engineers are not trained to use renewable energy technologies*** and most are not aware of the principles of sustainability. There is therefore an urgent necessity to develop and implement new courses that prepare engineers and scientists to work with and produce renewable energy systems [5]. Therefore, in the present paper the "***Building Expertise on Energy Sustainability (BEES)***" **model** is proposed, the model is a comprehensive approach composed of four key components, which are: 1) **Education**, 2) **Research**, 3) **Outreach**, and 4) **Connection** (Figure 1). Each key component consists of a set of structured activities, and details for each component are provided next.

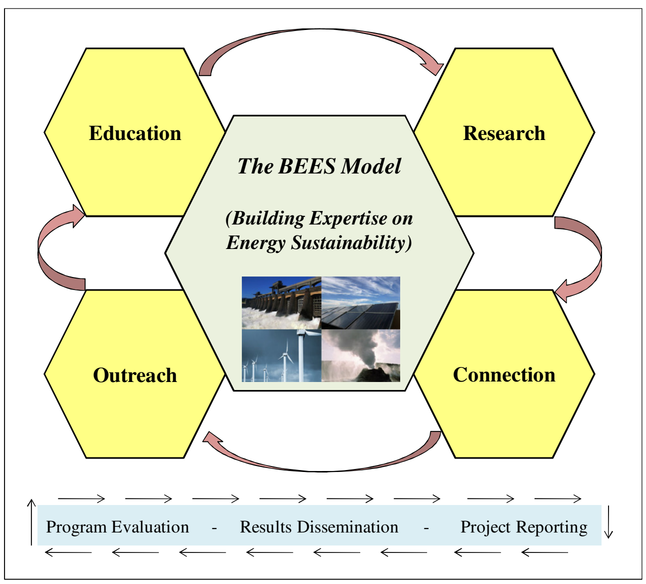

Figure 1. The BEES Model: Building Expertise on Energy Sustainability

2. Model Description

2.1 EDUCATION: According to *The Engineer of 2020* [12], to maintain the nation's economic competitiveness and improve the quality of life for people around the world, educators and curriculum developers must anticipate dramatic changes in science and engineering practice and adapt their programs accordingly. As part of this project, curricula in *Energy Sustainability* will be developed. The developed material will provide an understanding of conventional and sustainable energy production and utilization. The course will show the range of innovative technologies and put them in the context of the current energy infrastructure. The various alternative energy sources available, including renewable energy (hydroelectric, solar, wind, biomass, and geothermal), nuclear, and hydrogen will be analyzed. Each energy source's pros and cons based on our needs, availability, and environmental impact aspects will be discussed. Given the multidisciplinary component of the new curricula, junior and senior level students from different engineering majors will be able to register for the course.

The course will also contain several lab practices for hands-on learning. There will be different lab assignments; using the ***Hybrid Optimization Model for Electric Renewables*** (**HOMER®**) which is a free computer software developed by the National Renewable Energy Laboratory (NREL) used to model on and off-grid power sources. By using this software, students will experience ways to evaluate and analyze different design options for intelligent hybrid power systems. It will allow students to explore what renewable technologies are the most cost-effective and evaluate their impact on the environment. The tentative topics to be covered can be seen in Table 1.

Table 1. Proposed Curricula

<table>
<tr><th colspan="2">Renewable Energy Systems and Natural Resources (Draft Version)</th></tr>
<tr><td colspan="2">Course Description: This course will provide understanding of conventional and sustainable energy production and utilization that will serve as a foundation for Renewable Energy Systems and Natural Resources. The course will cover different innovative technologies and put them in the context of the current energy infrastructure. In this course, the various alternative energy sources available, including renewable energy (hydroelectric, solar, wind, nuclear, biomass, and geothermal) will be analyzed. Each energy source's pros and cons based on our needs, availability, and environmental impact aspects will be discussed.</td></tr>
<tr><td colspan="2">Course objectives:
• To learn about the energy situation and relevant economic and environmental issues;
• To understand the technical nature of energy and apply fundamental design concepts for efficient and renewable systems at both a community and site scale;
• To provide a systems approach to understanding state-of-the-art electric renewable energy systems.</td></tr>
<tr><th>Topics covered</th><th>Description</th></tr>
<tr><td>Introduction and overview</td><td>Relationship between energy, population and wealth, pressures facing the world due to energy consumption</td></tr>
<tr><td>Introduction and overview</td><td>Sociological, political and economic aspects, units of measure used in energy system</td></tr>
<tr><td>Systems tools for energy systems</td><td>Systems approach fundamentals, systems tools applied to energy, economic tools for energy systems</td></tr>
<tr><td>Climate change and climate modeling</td><td>Relationship between the Greenhouse Effect and Greenhouse gas emissions, modeling climate change, climate in the future</td></tr>
<tr><td>Fossil fuel resources</td><td>Characteristics of fossil fuels, decline of conventional fossil fuels and possible transition to nonconventional alternatives</td></tr>
<tr><td>The solar resource</td><td>Solar photovoltaic technologies, solar thermal applications</td></tr>
<tr><td>Wind energy systems</td><td>Using wind data to evaluate a potential location, estimating output from a specific turbine, economics of wind power</td></tr>
</table>

Nuclear energy systems	History of nuclear power, nuclear reactions and resources, nuclear energy and society: environmental, political and security issues
Hydroelectric energy systems	Introduction, Hydroelectric energy basics
Bio-energy	Introduction, the Biomass feedstock resource base, agriculture-derived Biomass resources, potential concerns and impacts
Geothermal power generation	Geothermal basics, Geothermal systems, Geothermal electricity generation
System Integration	Case studies from literature using HOMER
Lab: There will be different lab assignments; using the *Hybrid Optimization Model* for *Electric Renewables* (HOMER®) which is a free computer program developed by the *National Renewable Energy Laboratory* (NREL) used to model on and off-grid power sources. By using this computer based tool students will experience ways to evaluate and analyze different design options for intelligent hybrid power systems. It will allow students to explore what renewable technologies are the most cost-effective, their impact on the environment and also determine if the renewable resources used are an adequate power source.	

The new course is being offered as a technical elective class and is available for junior and senior level students from industrial, electrical, mechanical and civil engineering majors. Industrial Engineering students can relate several topics from the new class to some traditional IE classes such as Operations Research, Probability and Statistics and Design of Experiments.

2.2 RESEARCH: Undergraduate education requires a new transformative approach because learning is based on discovery guided by practice rather than on the transmission of information. The new course in *Renewable Energy Systems and Natural Resources* will be cross listed as an undergraduate and as a graduate course. A cap will be placed on the course to enroll 75% of undergraduate students and 25% of graduate students. The idea of having this combination of students is to increase the number of underrepresented students involved in undergraduate research experiences. The material covered in the newly developed class will provide several opportunities for research. Several recent studies have demonstrated the importance of undergraduate research in student learning [9, 17, 6], in the retention of diverse students in fields in which they are underrepresented and in students' pursuit of graduate education [11, 4]. By involving the students in research they have the opportunity to learn and grow, as well as to increase their chances of attending graduate school.

2.3 OUTREACH: via *Teaching Teachers Renewable Energy Systems and Natural Resources: creating a continuum* - Previous research indicates that hands-on learning experiences for teachers as well as for students offer a valuable, real-life instructional method for learning science and engineering, especially when it imitates authentic practice [10, 15]. Therefore, in the present proposal new lesson plans for teaching middle and high school teachers to teach *Energy Sustainability* will be developed. Moreover, these lesson plans will address a current state need, more specifically, the Texas 4-by-4 requirement for high school students who will have to complete 4 years of English, Math, Science and Social studies, *Texas Education Code*: Chapter 74 [18]. In the new requirement, the High School students will have to choose from different electives to satisfy the math requirements; **one of the technical electives is engineering**. The challenge faced by the school districts is: *how will current teachers with potentially little knowledge in engineering will teach engineering to high school students?*

To help El Paso's districts High Schools lessen this challenge, this project proposes to teach lesson plans to teachers participating in the **UTeach Miners program,** As part of the program, every summer, around 20-25 middle and high school teachers are recruited and supported for 6 weeks. The products that will be developed under the ***BEES model*** and shared with participating teachers are complete handouts including (*i*) student activities, (*ii*) classroom modules, extensions, and homeworks and, (*iii*) teachers handouts in the *Energy Sustainability* area.

2.4 CONNECTION: As mentioned by the National Research Council of the National Academies 2009 [13], academic programs tend to exist in isolation; therefore, there is a need to build stronger connections among institutions. To address this need, at least 1 invited speaker per year will be invited to come to our institution with the objective of reviewing the curricula developed, share the material developed and explore ways for future collaboration. Additionally, the faculty members coming to the university will be asked to give a seminar presentation to students and meet with other faculty members to build strategic partnerships.

3. Evaluation Plans

Two main types of evaluations will be performed during the present project to ensure that we are meeting the key objectives of this work: *1) formative evaluations* which will be used to provide us with continuous feedback on whether we are meeting our objectives, and *2) summative evaluations* which will be used to measure how effectively the proposed model accomplished its stated goals.

3.1 Formative Evaluation - Qualitative research techniques (peer review of curriculum materials, student interviews, and peer review of material by other faculty) will be used for formative evaluation purposes. These techniques have the advantage of providing detailed descriptive information which is useful for project improvement purposes.

Peer review of curriculum materials by Engineering Education experts and by faculty in the Energy Sustainability field - This project will produce curricular materials (class modules, laboratory exercises, and research projects). External experts in the field of Engineering Education from the Center for Effective Teaching and Learning at UTEP and faculty from other HSIs will be invited to UTEP to review and assess the material developed.

Student interviews - The instructional materials developed will be pilot-tested in the Spring 2011 semester. At the end of the semester, ten randomly selected students will be interviewed. This interview will focus upon their experiences with the instructional materials and how these experiences influenced their future educational goals and decisions. The individual interviews will allow the investigators to acquire a detailed understanding of students' experiences with the instructional materials.

3.2 Summative Evaluation- The Kirkpatrick Model [7, 8, 2] methodology will be used to perform summative evaluations, it is a four-level model of evaluation, in which Level one measures participant reaction. Level two measures new learning. Level three measures behaviors in the real world and, level four measures the results.

<u>*Level One: Reaction*</u> - Students at the beginning and end of the semester will complete an attitudes survey. This survey will help to determine whether students' participation in the *Energy Sustainability* class has stimulated their interest in this area.

<u>*Level Two: Learning*</u> - Through a collaborative effort between the investigators, a pretest/posttest assessment instrument will be developed. The resultant instrument will be included in the expert review that was described in the formative section of this proposal.

<u>*Level Three: Behavior*</u> - This measure will evaluate student retention of new research skills covered in the new *Energy Sustainability* course.

<u>*Level Four: Results (Retention statistics)*</u> - The number of students that select to continue to pursue a graduate degree in a *Energy Sustainability* related area will be tracked. This data will suggest whether the newly developed course contributes to student retention in this area.

4. Conclusions

In the present paper, the *Building Expertise on Energy Sustainability (BEES)* model is presented, the model will be implemented over a three year period. The main components (Education, Research, Outreach and Connections) will be evaluated using different formative and summative evaluations. The results obtained will be documented and presented in forthcoming educational related conferences.

Acknowledgements

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