AC 2012-4960: A MULTI-DISCIPLINARY AND MULTI-INSTITUTIONAL APPROACH TO PREPARE INDUSTRIAL ENGINEERS TO RESPOND TO FUTURE ENERGY CHALLENGES

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A Multi-Disciplinary and Multi-Institutional Approach to Prepare Industrial Engineers to Respond to Future Energy Challenges

Abstract

There is a world-wide necessity to increase energy efficiency, finding new alternative sources of energy and assessing the environmental impacts of new renewable energy technologies. Demand for professionals with sustainable energy knowledge is increasing, as employers need graduates who can better respond to energy challenges in all professional and business contexts. This demand will also create green-collar jobs in the industrial sector and in new technology fields. In light of these crucial needs, the University of Texas at El Paso, New Mexico State University, Texas A&M University-Kingsville and Texas State University-San Marcos united efforts to create a regional network of researchers to advance knowledge in renewable energy research and education. This paper introduces the BGREEN (BuildinG a Regional Energy and Educational Network) project and shows how industrial engineers at the different participating institutions will benefit. BGREEN is a multi-disciplinary project which promotes collaboration among different universities, colleges, departments and a federal agency, the United States Department of Agriculture. This type of collaboration is fundamental since the scale and nature of energy challenges requires expertise from a wide variety of disciplines. It has been found that multi-disciplinary approaches to research and education are essential to understanding and resolving complex environmental and social issues. Through BGREEN, students will experience that most real problems are not defined within a single domain but they cross disciplines. This paper highlights the education component of BGREEN and shows how industrial engineering departments can broaden and strengthen their research areas through the type of multi-disciplinary research performed under this project. The paper also shows how the BGREEN model can be easily replicated at other institutions.

1. Introduction

Today's energy challenges stem from an unsustainable energy infrastructure, largely dependent on fossil fuels, with clear implications for America's economic and national security. To that end, 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. 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 [1]. 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[2]. Building, operating, and maintaining a Sustainable Energy infrastructure will require a considerable expansion of the nation's human capital, which will only be developed through intense collaboration among multiple players. However, the scale and intensity of current energy education efforts in the United States remain inadequate to produce the needed technological progress and human capital development[3].

This paper introduces the BGREEN (BuildinG a Regional Energy and Educational Network) project. BGREEN is an integrated research and educational project supported by USDA by a multi-million dollar grant. The project promotes collaboration among different universities, colleges, departments and a federal agency, the United States Department of Agriculture. Each of the partners in the BGREEN consortium has an important role in shaping a vision of a more Sustainable Energy future and the education means to achieve it. Table 1 shows the breadth and diversity of the faculty involved. The range of resources and activities that are available across the four partner institutions provide unique opportunities for students to engage in interdisciplinary Sustainable Energy education and cutting-edge research exploration.

Table 1. Department name* and number of faculty members per department involved in BGREEN

Lead institution	**Institution 2**	**Institution 3**	**Institution 4**
PI (IE)	**PI (IE)**	PI (Agro & Res Sci)	**PI (IE)**
IE (2)	**IE (2)**	Agro & Res Sci (3)	**IE (1)**
CE (2)	CE (1)		Ag (1)
Chem (1)	Ag Econ & Ag Buss (1)		Chem (1)
ESE (1)			

** IE (Industrial Engineering), CE (Civil Engineering), Chem (Chemistry), ESE (Environmental Science and Engineering), Ag Econ & Ag Buss (Agricultural Economics and Agricultural Business), Agriculture Agro & Res Sci (Agronomy and Resource Sciences), Ag (Agriculture).*

This type of multi-disciplinary collaboration is fundamental since the scale and nature of energy challenges requires expertise from a wide variety of disciplines. From a research point of view, a multi-disciplinary approach is essential to understand and resolve complex environmental and social issues. From an educational point of view, it provides students with the ability to recognize that most real problems are not defined within a single domain but they cross disciplines.

As it can be noticed from Table 1, five out the sixteen investigators involved in BGREEN are from Industrial Engineering Departments. However, what needs to be highlighted is that three out the four institutional Principal Investigators are from Industrial Engineering Departments. This shows how Industrial Engineering is taking the lead in exploring new research and education opportunities to address current and future challenges in the renewable energy systems field. The collaboration with other departments and institutions will open new opportunities and provide industrial engineering students with a unique skillset and competitive advantage in the green energy economy.

2. Identification of the Educational Need

As part of a broader national crisis in science and math education, institutions of higher education, public and private sectors struggle to train and retain talented specialists in sustainable energy [4, 5]. It is no exaggeration to say that energy is figuratively and literally the fuel that drives our society, our economy, and our impact on the environment. Environmental concerns about energy production and consumption, especially the effects of fossil-fuel combustion on air quality and climate change, have further clarified the non-sustainable nature of our current patterns of energy use. It is clear that human capital development in the Sustainable Energy area is vital to the discovery of sustainable energy solutions. This need will diminish as more professionals and technicians are trained in renewable energy systems.

In this end, the multi-institutional BGREEN team identified a lack of curricula in Sustainable Energy-related topics not only at the regional level but also at the national level. To respond to this problem, multi-disciplinary faculty teams from the University of Texas at El Paso, New Mexico State University, Texas A&M University-Kingsville and Texas State University-San Marcos will work with the United States Department of Agriculture and agricultural research agencies to prepare students and graduates who can develop efficient renewable energy sources, incorporate biomass conversion, improve feedstock logistics, optimize supply chains and processes, and develop green infrastructure, as they enhance the competitiveness of our nation in the global economy.

3. Educational Need Areas

The present project seeks to meet four educational need areas:

(a) Curricula Design and Materials Development,
(b) Instruction Delivery Systems,
(c) Student Experiential Learning, and
(d) Student Recruitment and Retention.

(a) Curricula Design and Materials Development

BGREEN is a STEM project that supports the integration of agricultural sciences with the basic and applied aspects of the traditional STEM disciplines[6]. The focus of BGREEN is to meet current and future sustainable energy workforce needs, and to better prepare students to work at different USDA agencies. Therefore, curricula will be developed/adapted based on inputs from faculty and USDA leaders. A curriculum development team has been established with members representing university and USDA leaders. The curriculum development team will assist in the development of curriculum based on USDA needs, employability, and transferability requirements.

The next section demonstrates the courses we are implementing to incorporate sustainable energy topics into the industrial engineering curricula. Three courses are being developed: (1) Bioenergy logistics & its supply chain, (2) Renewable energy systems[7], and (3) Sustainability Engineering[8,9]. The courses developed can be taken as technical elective courses by Industrial Engineering students or any other junior or senior level engineering student. The main objective in all of the courses is to provide the students with novel tools which will help them understand how different industrial engineering techniques are applied in non-traditional fields. A description of the courses, the educational goals, and the main topics covered in these courses is shown in Table 2. This shows how Industrial Engineering is evolving and adapting to prepare future professional who can better respond to current and future national needs.

Table 2. Description, Educational Goals, and Main Topics of New Bioenergy Curricula

Bioenergy logistics & supply chain	Renewable Energy Systems	Sustainability Engineering
This course will provide understanding of feedstock logistics and its supply chain. The material presented will encompass all of the unit operations necessary to move biomass feedstocks from the land to the biorefinery and to ensure that the delivered feedstock meets the specifications of the biorefinery conversion process.	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 covers 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, and environmental impact aspects will be discussed.	This course in sustainability engineering is interdisciplinary and covers design, manufacturing, supply and systems aspects of sustainability engineering. The course will present the case for global sustainability, energy management, design for the environment, carbon footprint analysis, degradation studies, Life Cycle Assessment (LCA) and computer modeling
Educational Goals	**Educational Goals**	**Educational Goals**
• To learn about the logistic operations of biomass; • To understand the impacts of agronomic and agribusiness practices on feedstock sustainability • To understand how to reduce the cost of preprocessing within the feedstock supply system by increasing the efficiency and capacity of preprocessing equipment • To learn about methods of handling and transporting biomass feedstocks	• 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 • To perform an economic analysis considering different renewable energy alternatives • To apply optimization tools in renewable energy systems integration and smart grids	• Evaluate life cycle analyses of products and/or processes and propose strategies for addressing environmental impact while still meeting design and economic requirements. • Conduct a material selection with a goal of reducing the environmental impact of a product and/or process while simultaneously reducing material costs. • Propose design changes to a product to enhance recycling, reuse and/or remanufacturing capability with consideration of the economics of these activities. • To apply Decision Making tools to select from a set of possible design alternative.
Main Topics	**Main Topics**	**Main Topics**
• Introduction to feedstock logistics • The emerging biobased economy • Industry Technological barriers • Biofuels and bioproducts conversion technologies and systems • Estimation of feedstock inventory and supply • Feedstock logistics and systems simulation • Systems analysis of logistic operations, modeling • Economic analysis of the feedstock supply chain	• Introduction and overview: fossil fuels • Climate Change and climate modeling • System Tools, Power Grid, Smart Grid • Solar Systems • Wind Energy • Nuclear Energy • Hydroelectric Energy systems • Biomass and Biofuels • System Integration and Economic Analysis	• Introduction to Sustainability Engineering • Green Engineering concepts • Ethical Consumerism • Life Cycle Assessment • Energy Management • Energy Audits • Design for Sustainability

(b) Instruction Delivery Systems

Through inter-institutional collaboration with our partners and direct participation of USDA Agricultural Research Service (ARS), we will offer some course material and graduate strengthening seminars through video conferencing. We will also develop joint curricula/courses that will avoid duplication while utilizing the most advanced information and science from USDA ARS research. The Southern Plains Area office of ARS has the capacity to broadcast seminars and other lectures not only to all ARS locations in the area but also to the collaborating universities. We plan to utilize this capacity to improve our educational delivery approach.

(c) Student Experiential Learning

Different studies have demonstrated the importance of undergraduate research[10,11] in the retention of diverse students in fields in which they are underrepresented and in students' pursuit of graduate education[12,13] . In the present project, two different types of research experiences for undergraduate and graduate students will be offered.

- Summer Research Experiences (SRE) at USDA labs: Every summer, students across the participating institutions will be selected to conduct research at USDA labs to further the development of their scientific and professional competencies outside the classroom by immersing them in real-world problems. This opportunity will be provided to students on a competitive basis. The students will have access to state-of-the-art equipment and will have the opportunity to work with renowned USDA researchers.
- Summer Research Experiences (SRE) at Partner Institutions: At each of the participating institutions, students will have the opportunity to conduct cross-disciplinary research under faculty supervision to cultivate an interest in research through exposure to various types of research and the development of research skills.

The summer research experiences provide students with an opportunity to conduct full-time research. Additionally, it is expected that the experiences will:

- Increase retention rates and decrease the time to graduate,
- Encourage students to enroll in graduate school,
- Improve student confidence and communication skills through oral and written presentations of project results,
- Encourage student participation at national and regional conferences, and
- Increase student interest to work for USDA

(*d*) *Student Recruitment and Retention*

BGREEN will recruit and retain students interested in being part of the next generation of Sustainable Energy leaders. Each of the institutions in the consortium will participate in established K-12 outreach activities at various outreach programs (i.e., ExciTES summer program, pre-freshman Engineering Program (PREP)). Additionally, in each semester, events and extracurricular activities will be carried out at each of the partner institutions to ensure a proper cohesion of the participating students funded through this program (i.e., speaker seminar series, scientific method workshop, career activities, field trips, picnic day at the end of the semester, etc).

4. Main Components of the BGREEN Model

BGREEN adopts an integrated approach to advance Sustainable Energy research and education which bases its strength in identified regional and national needs to educate and train future sustainable energy leaders. As shown in Figure 1, BGREEN is composed of four key components: 1) *Outreach & Recruitment*, 2) *Education*, 3) *Experiences*, and 4) *Dissemination.*

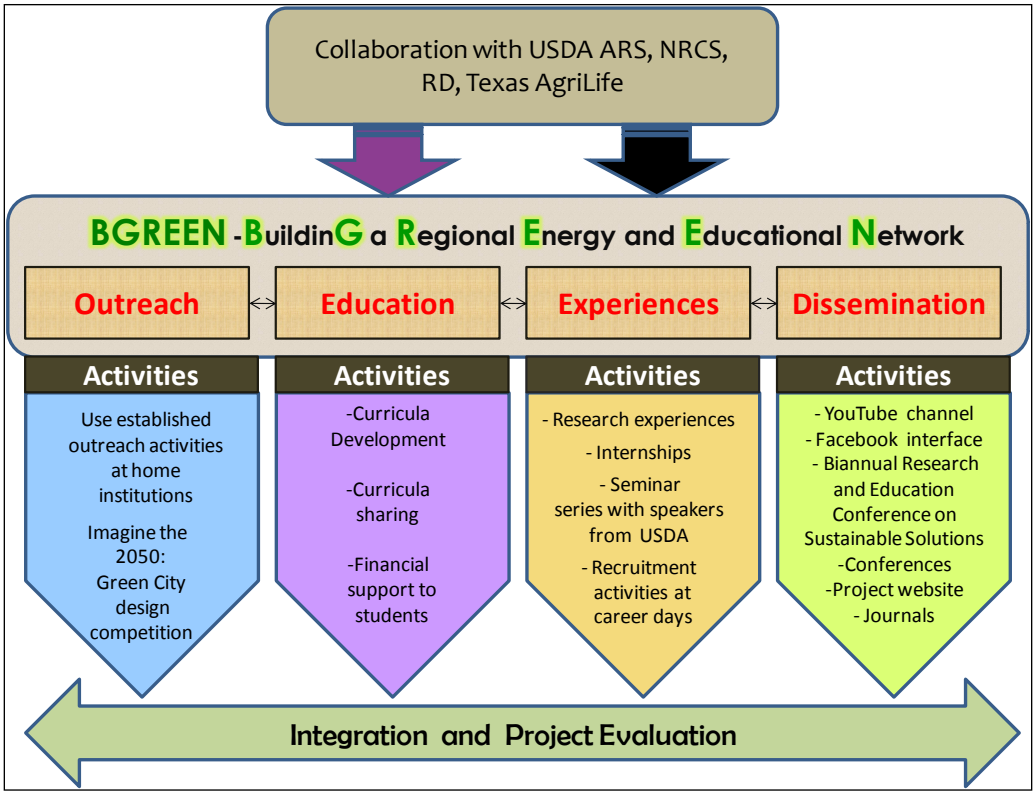

Figure 1. BGREEN Main Components

Each key component consists of a set of structured supporting activities as mentioned next:

(1). OUTREACH & RECRUITMENT

- *Design Competition*: the "*Imagine the 2050: Green City Design Competition"* will be organized and held at each of the participating institutions to involve local middle and high school students and teachers in discovering sustainable energy solutions.
- *Job Fairs:* the consortium will invite USDA to attend job fairs at partner institutions for recruitment activities of workforce for USDA agency.
- *K-12 Outreach:* partner institutions will use established outreach activities at home institutions to promote the BGREEN program and encourage students to pursue careers in STEAM disciplines.

(2). EDUCATION

- *Develop New and Reshape Curricula*: through the Curriculum Development, Transferring and Implementation Committee, the consortium will develop new and reshape curricula in collaboration with USDA to better prepare students for USDA

related careers. CDTIC will promote sharing of materials developed among collaborating institutions to avoid duplication of efforts.

- *Research:* the consortium will include research projects in courses as part of an integrative education.
- *USDA Seminar Series:* The consortium will organize a seminar series to feature presentations from USDA researchers. Presentations will be recorded (if permitted by speakers and data confidentiality) and will be made available through Project's YouTube Channel.
- *K-12 Education:* lesson plans and case studies in Sustainable Energy (bio-energy) will be developed to be used in K-12 outreach programs to attract students to pursue careers in sustainable energy.

(3). EXPERIENCES

- *Summer Research Experiences at USDA*: the consortium will offer summer internships at USDA research centers.
- *Summer Research Experiences at Partner Institutions:* participating faculty will provide research experiences at our consortium campuses to engage students in research development and encourage their participation in regional/national conferences.

(4). DISSEMINATION

- *Conference:* the consortium will organize a *Research and Education Conference on Sustainable Energy Solutions*.
- *Project Website:* we will develop and maintain a project website to highlight and promote the concept of the BGREEN model.
- *Facebook Page:* the page will enable communication among all investigators participating in the project to explore and document opportunities for future collaborative efforts.
- *Presentations/Publications:* participating faculty and students will give presentations at national/regional conferences per year, and submit work for publication in peer reviewed journals/conference proceedings.

5. Expected Impact

BGREEN is a four-year project that is expected to impact an average of 42 students per year, out of which many will be industrial engineering students. The level of study and the number of students supported by BGREEN is shown in Table 2.

Table 2. Level of study and number of students financially supported through BGREEN

INSTITUTION	Level of study of supported students											
	Year 1			Year 2			Year 3			Year 4		
	UG	MS	PhD	UG	MS	PhD	UG	MS	PhD	UG	MS	PhD
Lead Institution	2	4	4	2	4	8	2	4	8	2	4	4
Institution 2	4	0	4	4	2	4	4	2	4	4	2	4
Institution 3	6	2	1	6	2	1	6	2	1	6	2	1
Institution 4	9	3	---	9	3	---	9	3	---	9	3	---
SUBTOTALS	21	9	9	21	11	13	21	11	13	21	11	9
TOTAL / YEAR	39			45			45			41		

6. Project Evaluation

The BGREEN project will be evaluated by an external and independent evaluator. The primary intent of the evaluation is to contribute to the achievements and success of the project as it unfolds and evolves. To do this, the plan is composed of two strands of work that include internal continual assessments and external periodic reviews. Both strands will be fully interwoven and seamlessly embedded into the fabric of the project. The first strand is qualitative and formative and it is intended to gain insight into the successes and concerns about the project as perceived by all stakeholders. The purpose is to keep project leaders at the upfront of the project and allow them to make necessary mid-course adjustments based on relevant and timely information. To do this the External Evaluator will conduct focus group surveys and discussions project with faculty, students, and administrators. The second strand is quantitative and summative. The External Evaluator will constantly receive information about the project's progress and status related to the four educational areas that BGREEN addresses. At the onset of the project, baseline data about each product will be gathered and recorded. Based on a combination of the formative and summative process, special attention will be given to deducing lessons being learned, *i.e.*, positive and negative findings, unanticipated outcomes, and new opportunities to boost the overall intent of the project.

7. Conclusions

In the present paper, the BGREEN (BuildinG a Regional Energy and Educational Network) project is presented. The main components of the proposed model are 1) Outreach & Recruitment, 2) Education, 3) Experiences, and 4) Dissemination. The main objective of the paper is to demonstrate how modifications in the Industrial Engineering curricula will allow us to better prepare industrial engineering students to participate and take the lead in the green energy economy. The project also shows the multidisciplinary nature of the Industrial Engineering profession since many of the traditional tools can be used to address current and future engineering challenges in different emerging areas. The lead in this large collaboration effort is mostly undertaken by Industrial Engineering faculty, this shows how Industrial Engineering is evolving and adapting to prepare future professional who can better respond to current and future national needs. The BGREEN model is focused on the renewable energy systems area. The model and curricula can be easily replicated at other institutions. Undoubtedly, there will be many challenges to overcome in the near future to achieve the level of success set by BGREEN. However, all the participating investigators understand the requirements, work and effort needed to make a multi-disciplinary and multi-institutional approach like BGREEN a success.

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