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Incorporating Sustainability and Green Design Concepts into Engineering and technology Curricula

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Abstract

Human society is facing an uncertain future due to the present day unsustainable use of natural resources and the growing imbalance with our natural environment. Sustainability is an endeavour with uncertain outcomes requiring collaboration, teamwork, and abilities to work with respect and learn from other disciplines and professions, as well as with governments, local communities, political and civic organizations. The creation of a sustainable society is a complex and multi-stage endeavour that will dominate twenty first century. Sustainability has four basic aspects: environment, technology, economy, and societal organization. Schools with undergraduate engineering or engineering technology programs are working to include sustainability and green design concepts into their curricula. Teaching sustainability and green design has increasingly become an essential feature of the present day engineering education. It applies to all of engineering, as all engineered systems interact with the environment in complex and important ways. Our project main goals are to provide the students with multiple and comprehensive exposures, to what it mean to have a sustainable mindset and to facilitate the development of the passion and the skills to integrate sustainable practices into engineering tools and methods. In this study we are describing our approaches to incorporating sustainability and green design into our undergraduate curricula and to list a variety of existing resources that can easily be adopted or adapted by our faculty for this purpose. Our approaches are: (1) redesigning existing courses through development of new curricular materials that still meet the objectives of the original course and (2) developing upper division elective courses that address specific topics related to sustainability, green design, green manufacturing and life-cycle assessment.

Keywords*: Sustainability, green design, engineering and technology, curriculum*

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Introduction

The global challenges relating to issues such as food, water, environment, energy, health and so many more have never been more prominent in the United States and other developed or undeveloped countries than they are today. The current practice of our society is unsustainable, reflected by the major issues, such as population growth, increasing energy use and demand, climate changes, pollution and the fast depletion of natural resources. Nowadays, society needs a change of paradigm towards a sustainable society. It is an urgent change requiring a commitment for all the involved agents. To achieve this change, higher education plays an important role and, specifically, the scientific and technological education has a huge responsibility with its transitive role. The graduates in technology must contribute with effective solutions to the present environmental problem and new means of production to cover present and future needs for humankind, means that allow to reach and to maintain a fair and sustainable society, (Crewe and Mitchell, 2002, Maxwell and Van der Vorst, 2003, Allen and Shonnard, 2003, Gete et al, 2015).These facts results in an increasing motivation to incorporate concepts of sustainability into the undergraduate engineering curricula. Moreover, the Accreditation Board for Engineering Technology, Inc. (ABET, 2010 and 2013), requires that graduates be able "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". There are several initiatives to promote the sustainability of engineered systems and energy efficiency, while still improving the quality of life, looms more immediate. Not only accreditation boards and professional organizations but many corporations are concerned with sustainable development to reduce costs and liabilities and to create products that help improve the quality of life (Crew and Mitchell, 2002, Clift, 2006, Felder and Brent, 2004, Mulder, 2006, Hommberd et al. 2008, Jennings, 2009, Desha et al., 2009, 2010, Belu, 2009). Unfortunately, not too many universities are offering courses or training related to the sustainability, energy efficiency, green design, green manufacturing and renewable energy. However, many schools with undergraduate engineering programs are working to include sustainability and green design into their curricula. The approaches for doing so can be subject- and/or problem-oriented or could be part of a capstone experience. On the other hand, sustainability can also be an opportunity to satisfy the general education component of ABET criteria.

Solutions to these challenges require a thoughtful multidisciplinary approach that includes considerations of economics, politics, quality of life, and cultural and social norms, in addition to scientific and technological developments. Sustainability is becoming an important topic in technology, engineering and industry, as contribution of these areas to safeguard our future, and as evolving market segments. Manufacturing high productivity in combination with short life cycles of most of the industrial products and, on the other hand, growing resource problems of our planet, lead to a necessity that engineers take their share of responsibility for sustainability. Therefore, we need to include the concept of sustainability and green design into the university engineering and technology curricula, implying teaching new design methods and practice, new engineering and technology courses, curricula, laboratories and experiments. Sustainability concepts are increasingly important among governments, consumers, researchers, engineers, and corporations. Sustainability has four basic aspects: the environment, technology, economy, and societal organization. Declining in environmental, social, and economic conditions worldwide require adequate responses from the science, technology and higher education communities, since many solutions are intrinsic related to them. Engineers are playing a significant role in the 21st century in designing and implementing creative solutions to these challenges that threaten our very existence. Current engineering curricula typically do not fully address important sustainability considerations, except in a few capstone courses. Conventionally, engineers are taught to deal with technology development and economic analysis to assess the economic viability of a process, a product or a project. They usually are not very familiar with the optimization of the human benefit from the technology development and the environment where materials and energy are available. To prepare the 21st century engineer, sustainability needs to be covered systematically throughout the curriculum and in all majors. Schools with undergraduate engineering programs in many disciplines are working to include environmental sustainability and sustainable design into their curricula. Sustainable engineering is about design that recognizes the constraints that are applied by natural resources and the environmental system. It applies to all of engineering, as all engineered systems interact with the environment in complex and important ways. The needs for engineering students and practicing engineers to understand sustainability concepts and concerns have been noted by many educators, scientists or engineers, and it is the philosophy of the authors that all engineering students need to become versed in sustainability ideas.

U.S. college students enrolled in industrial, engineering, manufacturing, and systems programs will eventually face the same problem as Drexel University (DU) and the University of Texas at El Paso (UTEP) engineering graduates are facing right now, i.e., how to serve the growing demand for a new generation of global renewable energy engineering capabilities, especially when green energy products are becoming more important in the context of international operations and trade. Traditional engineering curricula do not prepare students well for handling the problems related to sustainability and green energy, arising from globalization of the industry. Large multinational companies are cognizant of impending overseas growing demand for a new generation of green products, and they are beginning to formulate their response to such growth. People at all levels must be educated regarding the need of emerging energy technologies, their uses and roles in the alleviation of growth in energy demand for the future. In addition, it will be imperative to create a highly educated workforce that can contribute to deal with challenges associated with renewable energy sources. One method of supporting work-forces development in future energy solutions is to incorporate new and emerging technologies into required undergraduate coursework. Engineering and technology educators must develop new curriculum solutions in advanced technologies to fill the gaps in existing coursework and prepare the next generation of students to support renewable energy, green design, energy efficiency, and sustainability.

Sustainable development is now a common practice in developed countries. Several engineering societies within the U.S. have made declarative statements on their commitments to sustainable development. Many companies are directing their resources to reduce the environmental impact of their products and services, to remain competitive in the global economy (Keijzers, 2002, Ghete et al., 2015). The companies must recruit employees who understand and possess the knowledge of the impacts of their decisions on the environment and society. It is the mission of universities to prepare these future employees to meet this need. Green manufacturing and design for sustainability are emerging fields in recent years and a sustainable development model for modern industries. They encompass the concept of combining technical issues of design and manufacturing, energy conservation and efficiency, pollution prevention, health and safety of communities and consumers. Many industries are directing their efforts to reduce the environmental impacts of their products and services. On the other hand, to remain competitive in the global economy, the industries need to train engineering and professionals to understand the impact of their decisions on the environment and society (Walker, 2006, McNamee, 2008, Ehrenfeld, 2008, Desha et al. 2009 and 2010). It is important for universities to prepare these future engineering technologists to meet this need. Many technology programs do not offer this type of information to their undergraduate students. However, the Accreditation Board for Engineering and Technology (ABET, 2010 and 2013) requires that graduates be able "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 ". The topic of sustainability has become part of corporate strategy, consumer choice processes, university initiatives, engineering, and technology programs. We are moving toward more sustainable business sand technology practices and education, covering a broad spectrum, from development of green products, implementation of advanced manufacturing and production technologies, energy efficient and environmentally friendly manufacturing processes, from the plant floor to the enterprise level, and the whole supply chain. We are interpreting green manufacturing as follows:

1. Manufacturing of green products.
2. Manufacturing process and system control to address energy and environmental concerns, reducing waste, and pollution, minimizing natural resource and energy use, extended recycling and reusing, etc.
3. Changing the education to include sustainability, green manufacturing, and efficient design into the engineering and technology curricula.

The authors are presenting results of a project funded by the US Department of Education on green manufacturing and design, sustainability and renewable energy to increase the enrolment and retention of the minority students in engineering and technology programs. This is a joint project between Drexel University and University of Texas at El Paso. The main goals of our projects are to provide the students in our programs with multiple and comprehensive exposures to the concepts of green design, sustainability, renewable energy, and skills needed to integrate sustainable practices into industrial engineering tools and methods. The expected outcomes of this integration include increased student' interests in engineering and technology, retention, social responsibility; development of innovative thinking skills; better understanding of sustainability issues (Belu, 2011 a, b, Belu and Husanu, 2012, Chiou et al. 2013, Tseng et al. 2014). This project is critical and holds a key role in enhancing the ability of future engineering graduates to better contribute to a more sustainable future,

preserving natural resources and advancing technological and societal development. The objectives of this study were to describe our approaches to incorporating sustainability into the engineering and technology curricula and to list a variety of existing course resources that can easily be adopted or adapted by science and engineering faculty for this purpose. Our approaches described are (1) redesigning existing courses through development of new curricular materials that still meet the objectives of the original course and (2) developing upper division elective courses that address, in depth the specific. Some of us have embraced the notion that green energy products and production techniques are a competitive weapon.

Sustainability in Engineering Education and Practice

Green and sustainable engineering, manufacturing, and design are emerging engineering practice fields, being also sustainable models for modern industries. Design, development and production of products and processes that have reduced impacts on the environment and human health has become one of the strategic goals of corporations and research institutions, here in the US all over the world. Among reasons are better use of the resources, increasing competition, regulations, and public awareness. It is likely that future technology will have very little to do with creating fossil fuel-based products, processes and services. On the other hand in education, while knowledge, expertize and skills in the areas science and engineering fundamentals will be required, knowledge and skills in areas such as energy systems, built environment, environmental and chemical engineering, electricity generation, or combustion processes will change significantly. Consequently, engineers need to be educated in energy, efficiency, green and sustainable design methods. It is so critical that engineering graduates are equipped with relevant knowledge and skills to effectively address such challenges in society (Belu and Koracin, 2010, Belu, 2011 a,b, Belu and Husanu, 2012, Belu et al. 2013). However, to make this educational transition, it is critical to address a number of key elements within the curriculum renewal process, such as the industry needs, the demand for engineering graduates to be literate and competent in sustainable development, and the needs to meet changing student expectations on course content and curriculum.

An extensive literature research on sustainability, green manufacturing, green design, energy efficiency and renewable energy inclusions into the engineering and technology curricula, was conducted by the authors and the graduate students (Belu et al., 2013a,b, Belu and Husanu, 2013, Chiou and Belu, 2013, Belu et al., 2014), as part of our project. The main findings were that courses concentrate primarily on smaller systems, particularly those limited to the firm (design for environment) or product (life cycle analysis/assessment), while less are addressing larger systems that examine relationships between different industrial sectors (industrial ecology) or between industrial and non-industrial sectors (cultural and social dimensions). The authors also found that sustainability engineering materials were taught mainly to upper division and/or graduate classes, and while discrete sustainable engineering courses seemed to be the most common approach, materials are also incorporated throughout programs. The curriculum developed at our universities will provide the students with instruction about low-impact material and process selection (renewable, environmental impacts, embodied energy), energy efficiency (transportation, product processing and use), quality and durability, design for reuse/recycle, and social relevance/value, consumer value, and responsible production. While the authors are aware of the inter-relationship of these categories, we have isolated each one to make them easier to teach, explain, and assess. Our literature review suggested that there is an inherent inextricability between sustainability as taught in a classroom and as practiced in the field makes curricula embedding both challenging for the institution and particularly relevant to the lives of students after graduation. We also found that there is a growing interest in sustainability-related topics in universities, which may indicate a shift in the demands of students and employers. Many employers are looking to hire graduates that are socio-environmentally responsible. For the promotion, recruitment, and training of staff in terms of social and environmental responsibility, larger businesses were most demanding. It is not unreasonable to assume that broad trends will remain for at least a decade. While many universities have signed declarations pledging support of sustainability initiatives, most have fallen short in regards to implementation. Most failed attempts to embed sustainability cite a lack of leadership, incentives, knowledge, or resources when trying to implement new programs or add them to existing curricula. We also believe that support from university for the sustainability embedding is necessary to maintain a cohesive plan and implement it successfully; however, other universities have also yielded positive results from “bottom-up” approaches. Professional development of academic staff is a major factor identified as contributing to a high success rate among schools that attempt sustainability implementation. Resistance from academic staff was most common when it became

necessary to remove existing materials from curricula in order to make room for sustainability education.

Our approach in teaching sustainability, green manufacturing and design, energy efficiency and renewable energy is framed in the following contexts. 1) Technical sustainability addressing a wide range of factors related to design, energy efficiency, manufacturing processes, involving research, and appropriate technology supporting process and product function and development, as well as efficiency, durability, material selection, reduction, reuse, part disposal, maintenance and function capabilities that meet the designed product or process. 2) Environmental sustainable design, in which the engineering processes, products, and structures have less negative, neutral or benign effects on all environmental systems. 3) Economic and societal sustainability through the economic and social policies have impacts not only the efficient, profitable and sustainable development but also factors influence the economic health of communities, standard of living, business climate, employment, the productive role of the corporation in the employees' life, the role of the individuals, the family, collective behaviour, social class, health, medicine, etc. Our methodologies for integrating and teaching sustainability, green design, energy efficiency and renewable energy are taking traditional forms, such project-based, problem-based learning, hands-on, and teaching creativity skills and critical thinking. Teaching and learning are taking place in the in the contexts listed above by using integrated methodologies, in which students learn to analyse sustainability case studies, to develop and build sustainable and green designs, and assessing products and processes for sustainability and energy efficiency

Curriculum Challenges and Changes

Normal Nowadays, society needs a change of paradigm towards a sustainable society, an urgent change that requires a commitment for all the involved agents, industry, academia and government. Higher education is playing an important role, while engineering education has a huge responsibility with its transitive role. Our graduates must contribute with effective solutions to the present environmental problems and new means of production to cover present and future needs for humankind, allowing to reach and to maintain a more fair and sustainable society. Teaching green design, energy efficiency, sustainability, and renewable energy to engineering and technology students requires new approaches to course planning, lesson development, pedagogy, assessment, and student expectations. Equipping students with the skills and knowledge required to be successful global engineers in the 21st century is one of educators' primary objectives. Enabling students to practice self-directed learning, to find solutions to design problems that are sustainable and to recognize that they are part of a global community are few of our educational goals. However, transforming higher education curricula for sustainable development is a tough challenge to the curriculum developer and course designer. They will have to deal with the complexness of the sustainability concepts and integrate that into engineering education. Engineers have an enormous opportunity to help create a more sustainable society. By teaching engineering students sustainability principles, and equipping them with the tools to incorporate sustainability and green design principles and concepts into their work, they can make better choices on material and energy use, and the lifecycle of their design. Sustainability is still relatively new to engineering curriculum and is not a fully established practice for most of the engineering disciplines. Meanwhile, today's students have a strong desire to improve the world, and sustainability maybe one way to do this. Student' hunger for knowledge often outstrips what is available in their courses and the experiences of their professors. Furthermore, to make sustainable design compelling to engineering students, we need to craft sustainable design in terms of mainstream design problems that are important, cutting-edge, and achievable. Then we need to show them how to effectively deal with environmental and societal needs and constraints as part of their core design processes.

Our Implementation Approach

A two-level approach was taken in our curriculum changes to incorporate sustainability, green design and renewable energy subjects. A first level such topics, subjects and problems were introduced by the faculty involved in this project in their courses, where it is appropriate (Chiou and Belu, 2013, Belu et al., 2014, Tseng et al. 2014, Belu et al., 2015). Projects for the senior design project capstone course sequence were proposed and directed by the project investigators. Limited financial support was also provided, via grant funds for these senior design projects. At second level several courses on green manufacturing, industrial energy systems, and renewable energy were proposed, developed or underway to be developed. However, the efforts to integrate sustainability, green manufacturing, and renewable energy into our curricula have met with some resistance, such as: 1) opposition to adding new courses or integrating sustainability, green design, and renewable energy contexts into already tight curricula, 2)

the faculty inter-disciplinary expertise necessary to teach new sustainability, green design or renewable energy, 3) the resistance to revising existing senior design project courses, and 4) new laboratory infrastructure.

In our project, at both institutions several courses in renewable energy technology and systems, industrial energy systems, energy management, project-oriented green energy, green design and sustainability were developed. In these courses students from University of Texas at El Paso (UTEP) and Drexel University (DU) work on problem-focused projects on the above topics, while access to our virtual facilities and software allows students to explore the principles, characteristics and operation of various energy sources, storage devices, and energy conversion systems. The new learning materials allow DU and UTEP students to "see and feel" the emerging green technologies through interactive laboratory experiments and learning modules. The new courses address the industry needs and our program mission in sustainable and green design methods and practice: 1) To make clear the grand challenges driving the need for sustainable design, and to provide tools and examples useful for tomorrow's engineers to meet them; 2) Describe grand challenges technology poses for water, energy, and climate change along with the incentives and inhibitors to implementing sustainable design to meet these challenges; 3) Teach modelling approaches for estimating impacts of technology design choices on water pollution, air pollution, and global warming potential. Introduce life cycle assessment and predictive life cycle assessment as concepts along with software tools that facilitate their practice; and 4) Learn about sustainable design case studies that focus on the spectrum of product life cycle stages, as well as integrated end-use design, transportation, manufacturing, and consumer products that demonstrate sustainable design principles. A design project will have a positive impact on sustainability education or practice.

Sustainable engineering is, in many ways, more related to green engineering as it focuses on design that requires fewer natural resources, produces less (or no) waste, and reduces, reuses, or recycles waste products. Several approaches have been proposed clear educational objectives for incorporating sustainable development concepts into the undergraduate curriculum. The ABET accreditation criteria for engineering and technology programs also calls on programs to directly address issues of sustainability and environment. However, in an already crowded engineering curriculum, it is difficult to envision where and how these concepts can fit. In this paper, we refine the recommendations of others into yearly goals and objectives for the undergraduate curriculum. Given the increasing importance of sustainability, it is incumbent upon academia to educate future engineers and other decision makers on sustainability topics, i.e., incorporate sustainability into engineering and technology curricula. The sustainable development, green manufacturing and renewable option incorporates energy efficiency and conservation, energy sustainability, renewable energy, and carbon management of systems will be related to industrial processes, processes of commercial, and light commercial and residential facilities. Students learn a combination of technical and management theories designed to prepare them for careers in the green economy sector associated with facility management, energy conservation and efficiency, renewable energy, green manufacturing and design. This approach offers practice based theoretical knowledge in the classroom, laboratory experimental design, and hands-on experience. Ideally, graduating engineers would be able to create a process flow and a life-cycle inventory for competing product or process designs with the aid of software tools. From the inventory, they are able to assess the relative merits of the competing designs based on ecological and resource indicators. These advanced skills draw on the students' knowledge of their discipline. But they also require a set of analytical approaches that encourage holistic, system thinking. In systems thinking, one pays attention to the inputs and outputs of the system and their effects on the surroundings. These approaches can be easy integrated into the framework of existing curricula.

Promoting sustainability through curriculum design involves articulating what students will take away from a learning experience and connecting this outcome to some kind of assessment. Curriculum developers are usually using systematic, consistent frameworks to organize learning outcomes, activities, and assessments. The curriculum products include syllabus, course outline, and learning modules with associated assessments. These documents should be presented to learners upfront prior to any sustained learning experience whether it is a credit course, workshop, or seminar. Additionally, after a program and its associated courses are designed, curriculum maps show where program outcomes or other broad core abilities appear across courses. These deliverables are the vehicles by which sustainability is evidenced and communicated to learners and the public. In order to incorporate sustainability and green manufacturing principles and methods into engineering and technology curricula, we must understand the barriers that need to be overcome, such as: i) program accreditation, ii) conventional thinking of some faculty members, and iii) industry expectations and recruiting trends. While progress has been made in surmounting or reducing some of these barriers,

much improvement is still needed. The green manufacturing, renewable energy technology and sustainability skills and knowledge are required to meet the following objectives, including energy efficiency and management, sustainable facilities, planning and design, sustainable green construction, sustainable and green manufacturing, and renewable energy sources such as biomass, biofuels, solar power, and wind energy technologies. These are selected because they represent the green technologies with the highest potential impact in our areas. Development of a workforce skilled in these areas is essential toward sustaining a green economy in these regions. Several interdisciplinary, sustainability-related courses have been proposed, underway to be developed or developed and offered to our undergraduate students, including renewable energy courses. A life cycle engineering and environmentally responsible design and manufacturing seminar is also proposed to be part of this endeavour. Although these courses have created a quite high level of awareness among our students, they are not required of all students, and no pervasive sustainability theme has been established in our curricula. The authors believe that more information and real-world learning experience will be required in each curriculum to incorporate a sustainability theme. However, care should be taken and new innovative strategies should be explored.

Proposed New Courses

Dung first project phase we developed and offered several new courses in our programs. Two new at each institutions were in the area of renewable energy technology, while another ones are focusing on industrial energy systems, and energy management and sustainability, respectively. Last course planned to be developed in the next academic year focuses on green engineering and sustainable design. However, the renewable energy technology course at Drexel University was developed by one of the author was initially offered as a special topics course in 2009-2010 and 2010-2011 academic years, respectively. This course mainly focuses on the wind energy, solar energy, photovoltaic's and to a lesser extent on the other renewable energy sources and related technologies (Belu and Husanu, 2013, Belu et al. 2013, Chiou and Belu, 2013, Belu et al., 2014, Tseng et al. 2014, Belu et al. 2015). Since this course deals mainly with the analysis and the components of the wind and solar energy conversion systems, as well the analysis of integration and interconnection to the power system grid, the desired prerequisites include a course in energy conversion, and co-requisites a course in power electronics and power system analysis. Students are expected to be well around in general renewable energy issues, electric machines and energy conversion technologies. They are expected to be particularly skilful in analysing and solving wind and solar power systems and related problems. The aims and goals of the industrial energy systems course are to train students to use process integration methods and tools necessary for identifying and designing efficient industrial energy systems. Besides understanding technical and economic issues, students will also achieve understanding of the impact of industrial energy use on the greenhouse effect, and the role that industrial energy systems can play with respect to meeting greenhouse gas emissions reduction targets. The course addresses use of methods to identify the cost-optimal mix of different process heating technologies to satisfy a given process steam demand. One important aspect is how future energy policy instruments will influence these optimal solutions. Technical systems encountered in the course include heat exchangers, boilers, heat pumps, combined heat and power systems, and thermal separation units.

The energy management systems course was offered for first time in Fall 2014 quarter as a 3 credit hour special topics course. It comprises of 10 lectures, one class project/case study, one field trip to a local energy company, two research oriented take home tests, and a final examination. Since the course is open to people with diverse technical backgrounds, emphasis is placed more on applications and concepts rather than the core technical engineering principles. It aims to train students to use process integration methods and tools necessary for identifying, improving energy use and conservation. The course addresses use of methods to identify the cost-optimal mix of different energy technologies to satisfy a given process energy demands. Technical energy systems encountered in the course include electrical, thermal, and mechanical ones. The objectives of this course are to enable the student to understand the fundamentals of energy supplies and uses, and how energy can be used more efficiently. Other objectives are to enable the student to understand the methods of energy management in homes, institutions, businesses, large buildings and industrial facilities and processes, as well as the realistic potential of renewable energy sources, and to develop overall energy awareness and an efficiency ethic which can be used to help themselves and the organizations they work for. The course is a combination of lectures, case studies and real assessment projects with hands-on site assessment of at least two real industrial companies to introduce the student to the fundamentals of the concepts and systems in energy efficiency (Belu et al. 2015). Another course objective is to familiarize the students with the application of standards and codes such as NEC, NEMA, IEEE and IEC for building and

industrial electric and energy systems. This is a multidisciplinary course and in consequences we included required and recommended textbooks in the syllabus, as well as tutorials prepared by the instructor. The required and recommended references for this course are: Capehart B.L. et al, Guide to Energy Management, Doty, S. and Turner, W.C., Energy Management Handbook, Morvay, Z. and Gvozdenac, D., Applied Industrial Energy and Environmental Management, and Putman, R.E. Industrial Energy Systems: Analysis, Optimization and Control.

Green engineering and sustainable design, a hands-on course, aims to provide the students with the key approaches to advancing sustainability through engineering design. The course contains comprehensive discussions on the sustainability, metrics, general design processes, and challenges to sustainability. The current approaches to design, manufacturing, and disposal are discussed in the context of examples and case studies from various industry sectors, providing a basis for what and how to consider when designing products, processes, and systems to contribute to furthering sustainability. The fundamental engineering design topics to be addressed include pollution prevention and source reduction, recycling, separations and disassembly, material and energy efficiencies and flows, systems analysis, and life cycle assessment and design, management, and analysis. Students tackle current engineering and product design challenges in a series of class exercises, case studies and a final design project.

Student Projects

Engineering senior or capstone design courses fill a critically important role in the engineering and technology curriculum, forming a bridge between school and the workplace and have been extensively researched. These courses bring to the forefront many of the ABET outcomes such as lifelong learning, design, teamwork, and contemporary issues. On the other hand, even the sustainability is included in ABET's description of considerations for design but seldom incorporated into student projects. For the past years, our focus has been shifted towards incorporating more renewable energy, sustainability and green manufacturing topics in our senior design course sequence, as well as in adding research projects on these topics in several upper division courses, such as power electronics, energy conversion, power systems, etc. In the first senior design project term, we assign to our students the project topics related to renewable energy, power systems, or green energy manufacturing. These projects provide multi-disciplinary collaboration and valuable hands-on experience to the students. In addition to useful lessons on teamwork and project management, the projects provide working demonstration of green energy manufacturing systems. In the following will focus our discussion to the senior project courses, a three quarter sequence (Belu, 2009, Belu, 2011a,b, Belu et al., 2014). During the first fall quarter of the senior design course sequence, each team is given with guidelines for the senior design projects. Each team demonstrates the senior design proposal to the entire class and then a written proposal summarizing the proposed activities is handed-in as one of requirements of the senior project design course. Examples of the green energy manufacturing projects for the senior design course are:

1. High Efficiency Photovoltaic Charger Systems;
2. Indoor Solar Harvesting Energy for Sensor Network;
3. Solar Cell Surface Imaging for Quality Measurement;
4. Hybrid Energy Integrator for Green Factory;
5. GPS-based Dual Axis Sun Tracking;
6. Self-power Wireless Sensor Node for Coastal Monitoring;
7. Integrated Wind and Solar Powered Outdoor Area Lighting Kit;
8. A Digitally Controlled and Portable Photovoltaic Power Source
9. Design and Implementation of a Sovonius Micro-Wind Turbine
10. Self-Powered Rain Gauge and Weather Station

To enhance the hands-on experience, the senior design course sequence has been restructured as a project based course. Students are required to analyse, design, simulate, and build a completely functional system by the end-of-term project. The goals of all the projects are to explore and enhance student understanding of the fundamental concept of design-for-environment and hands-on learning of green manufacturing.

Conclusions and Future Work

This paper provides an overview of steps to initiate and implement sustainability, green engineering and green design concepts, methods and topics, renewable energy technologies, energy management, energy conservation and efficiency methods and techniques into our engineering and

engineering technology programs. More than one approach is used to incorporate these concepts and associated methods and techniques into our curricula. This consists of course adaptation to include the new concepts into the old curricula, developing new courses and laboratory experiments, proposing design projects with sustainability, green energy and design topics and contents, not only into the senior design project course sequence but also into the project-based upper level courses. Extensive assessments are underway or planned to be conducted all over second phase of project, begging with 2015 academic year. Lessons learned will be available for interested parties, instructors or researchers, through conference and journal papers, seminars, workshops or project website. While the present efforts are still in its first stages (phase I) of our project, we believe that there is much to expand upon, within both engineering and STEM programs, considering the critical importance of understanding the complex reciprocal influences each sustainability, green design, manufacturing and energy efficiency contexts have on the others aspects on engineering practice and education.

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