Embedding Renewable Energy Concepts into Engineering Curriculum

Dr. Radian G. Belu, Southern University

Dr. Radian Belu is Associate Professor within Electrical Engineering Department, Southern University, Baton, Rouge, USA. He is holding one PhD in power engineering and other one in physics. Before joining to University of Alaska Anchorage Dr. Belu hold faculty, research and industry positions at universities and research institutes in Romania, Canada and United States. He also worked for several years in industry as project manager, senior engineer and consultant. He has taught and developed undergraduate and graduate courses in power electronics, power systems, renewable energy, smart grids, control, electric machines, instrumentation, radar and remote sensing, numerical methods, space and atmosphere physics, and applied physics. His research interests included power system stability, control and protection, renewable energy system analysis, assessment and design, smart microgrids, power electronics and electric machines for non-conventional energy conversion, remote sensing, wave and turbulence, numerical modeling, electromagnetic compatibility and engineering education. During his career Dr. Belu published ten book chapters, several papers in referred journals and in conference proceedings in his areas of the research interests. He has also been PI or Co-PI for various research projects United States and abroad in power systems analysis and protection, load and energy demand forecasting, renewable energy, microgrids, wave and turbulence, radar and remote sensing, instrumentation, atmosphere physics, electromagnetic compatibility, and engineering education.

Dr. Richard Chiou, Drexel University

Dr. Richard Chiou is Associate Professor within the Engineering Technology Department at Drexel University, Philadelphia, USA. He received his Ph.D. degree in the G.W. Woodruff School of Mechanical Engineering at Georgia Institute of Technology. His educational background is in manufacturing with an emphasis on mechatronics. In addition to his many years of industrial experience, he has taught many different engineering and technology courses at undergraduate and graduate levels. His tremendous research experience in manufacturing includes environmentally conscious manufacturing, Internet based robotics, and Web based quality. In the past years, he has been involved in sustainable manufacturing for maximizing energy and material recovery while minimizing environmental impact.

Prof. Lucian Ionel Cioca, Lucian Blaga University of Sibiu

Lucian Ionel CIOCA received the M.Sc. in Machine Tools (1993) and B.Sc. in Occupational Safety, Health and Work Relations Management (2010). In 2002, he becomes Dr. Eng. (Ph.D degree) of Petrosani University, Romania and now he is professor at "Lucian Blaga" University of Sibiu - Romania, Faculty of Engineering, Department of Industrial Engineering and Management, Romania. His teaching subjects are Ergonomics, Management, Human Resources Management, Occupational Health and Safety Management, Production Systems Engineering. His research fields of interest are linked with the impact of the knowledge based society upon the social / human dynamics / evolution and the production systems. He regularly publishes and participates on international scientific conferences. Lucian Cioca is the Administrator of the LBUS Department of Consulting, Training and Lifelong Learning, Doctoral Advisor in Engineering and Management, Member of the National Council for Attestation of Academic Titles, Diplomas and Certificates, evaluator ARACIS (The Romanian Agency for Quality Assurance in Higher Education), and other (email: lucian.cioca@ulbsibiu).

Embedding Renewable Energy and Sustainability Concepts into Engineering and Technology Curriculum

Radian Belu, Southern University, Baton Rouge, Louisiana, USA
Richard Chiou, Drexel University, Philadelphia, Pennsylvania, USA
Lucian-Ionel Cioca, University "Lucian Blaga" of Sibiu, Romania

Abstract

Advances in the renewable energy technologies, green design and manufacturing combined with increased demands for graduates trained in these areas are requiring innovative curricula, new courses and laboratories to educate students to work in this rapidly developing industry and become acquainted with these new technologies. Moreover, the pace of change in engineering education is accelerating due to technology advances and administrative constraints. Educators are modifying curriculum content to embrace technological advances in the program or course learning outcomes. In modern world where everything changes at an extremely fast pace keeping up with technology changes is not only desirable but necessary. The renewable energy, green design and manufacturing are highly interdisciplinary, crossing boundaries between research areas, making difficult to cover each of them in a single course. However, they have a strong potential for multi-disciplinary and project-based learning approaches. The projects within sustainable engineering and renewable energy involve electrical, mechanical, civil, and chemical engineering aspects while still being accessible to undergraduate students. The paper presents the development, content and structure of a set of new courses and changes in several existing courses, as part a Department of Education sponsored project targeting the inclusion of such topics in our engineering and technology programs to increases the enrollment and retention of minority students. The motivation, outlines and content of the developed courses are discussed, as well as the outcomes, results and lessons learned with the inclusion of green energy projects. Materials presented herein may serve as template for other instructors considering offering similar courses, and their feedback is acknowledged and appreciated by the authors.

1. Introduction, Project Goals, Aims and Objectives

Major challenges facing our society, such as energy, water, environment or health have never been more prominent than they are today[1-3]. Engineers and educators, as problem solvers need to address these challenges in sustainable ways. Engineering practice and education are changing as technology, social expectations and conditions are changing too. Students have the responsibility and opportunity to continue improving our life while minimizing or even reversing the negative industrial society environmental impacts. Current engineering curricula are not fully equipping them to properly deal with these challenges[4-9]. These concerns, growing electricity demands, and energy market deregulation have increased the interest in sustainability, distributed generation and renewable energy systems (RES). Given the rapid progress in these areas, there are needs for professionals with adequate knowledge, able to plan, design and operate of such energy systems, assess and analyze energy resource potential, or to perform analytic evaluation of their impacts on power systems or environment[1]. Education, training and learning are important aspects that in taking the necessary steps to reshape our way of living into a more sustainable one. Time is running short therefore special attention needs to be given to the setting and developing undergraduate and graduate courses, laboratories, programs in these emergent areas of industry.

U.S. and many other countries are on the cusp of transformational changes in how energy is used and produced. Major investments are made by the governments and corporations in clean energy technologies and smart grids, creating entirely new industries, while expanding the markets for clean energy sources, and support weatherization and other energy efficiency efforts. A critical component of these efforts is to train our graduates in these emerging energy areas, to have a 21st century workforce[1-10]. These dramatic changes in the energy practices and technologies are also requiring the adaptation of engineering education. A critical component to make U.S., the world's leading manufacturer of new energy technologies and components, is the proper education of the workforce. It is also imperative that the policies and programs to encourage underrepresented minorities particularly women, Hispanics, natives, or Afro-Americans into such fields when in such earlier and nascent stages. Meanwhile in the last two decades, U.S. universities have experienced decline in engineering enrollment and low retention rates, especially among minorities. By investing in quality programs, it can go a long way to develop the potential and leadership skills in the field. Since the dropout rate in the minority groups is significantly higher, an effective way to retain students in engineering or technology programs is help them envision a future bright career, equipping them with strong academic training and hands-on experience that are meeting present and future job market needs. To develop new talent or leadership, it is necessary that the students gain confidence and mastery by training them appropriately and by giving ample opportunities to solve real world problems, through research projects and providing them internship opportunities, while their research findings should be introduced in the curricula to create a cycle of growth and learning.

In 2012, our institutions were awarded with a grant from U.S. Department of Education, proposing to fuse green energy, sustainability and green manufacturing concepts into the engineering and technology curriculum, enhance students', especially Hispanic students' knowledge in these areas using a holistic approach by providing new courses and laboratories, research support, seminars and workshops, internship and co-op opportunities[9,10]. *Goals, aims and objectives of our collaborative project are designed to align with the sponsor goals and objectives: 1) The project aims and targets to increase the entry, enrollment and retention level of women, minorities, with special attention paid to the Hispanic students in engineering majors at participating institutions; 2) The proposed green energy and IT-based engineering curriculum improvements aimed to provide hands-on instruction, skills, knowledge and experience which that are influencing undergraduate Hispanic and other minority students' decision to consider engineering as their major; 3) Dual programs for Community Colleges and summer programs as well as High Schools at one of the institution are providing access for pre-college minority and women students to careers in engineering and technology; 4) Our project aims to develop and establish an integrated research-oriented educational facility to support and enhance teaching and learning in these areas, by providing a set of comprehensive laboratory experiments, teaching and learning modules; and 5) The design and implementation of a computational workbench for simulating hybrid power systems and distributed energy resources.*

2. Curriculum Changes

Engineering and technology programs must offer a relevant and validated curriculum, preparing the students for post-graduation success. Courses that cover subject matter in mathematics, the sciences, materials, engineering economics and related topics provide the foundation of knowledge upon which specific skill sets are added depending on emphasis. It is also critical for engineering education, the transition from theoretical work to learning through experimental hand-on activities based on technology applications and design. In the area of renewable energy and sustainability, due to rapid development over past decades became obvious the need of training in both formal and informal systems. Therefore special attention must be given to developing programs at undergraduate level in renewable energy and sustainability, developing training programs for workforce in these emergent areas. Our engineering and engineering technology curricula cover fields such as electronics, electric machines, mechanics, robotics, manufacturing, mechanics, energy conversion, power electronics, instrumentation, materials and control. In order to prepare our graduates for 21st century industries it is necessary to learn about the renewable energy systems and their applications, sustainability, efficient energy use and sustainability[9-18]. Due to continuous growth in the use of renewable energy-based electricity generation and the needs of keeping students abreast of the current technology developments and trends, it is our strong beliefs that it was timely to develop and deliver courses on renewable energy technologies, energy management and industrial energy systems. One objective of this paper is to present our efforts in developing such courses and the supporting laboratories, to present the course outline and content, including projects, experimental activities, lessons learned and references. An important part of our project was the student projects and related activities.

A multi-level approach was taken in our curriculum changes to incorporate sustainability, green design and renewable energy subjects[9,12-18]. A first level such topics, subjects and problems were introduced by the faculty involved in this project in their courses, where it is appropriate. Next level, projects for the existing or proposed courses, undergraduate research projects, and senior design projects in the capstone courses were proposed and advised by the project investigators. Limited financial support was also available and provided, via grant funds for these projects. At third level several courses on green manufacturing, industrial energy systems, and renewable energy were developed and offered. Along with course development, substantial efforts were dedicated to update, equip, restructuring and add new experiments in the energy conversion, power electronics, green energy, manufacturing and industrial energy laboratories. In the same time a set of seminars on the green energy, green design and manufacturing, hosted by both participating institutions were scheduled every other year, while a 2-day workshop and training seminar was hosted every year in April, by the leading project institution. Students and faculty from both institutions were heavily involved in these seminars and workshops, and speakers form industry also invited. Last but not least significant efforts were paid to disseminate project results and findings through conferences, journal papers, website and media. However, our efforts to integrate green design, manufacturing, and renewable energy into our curricula have met with some resistance, such as: 1) opposition to adding new courses or integrating such topics into already tight curricula, or over-crowded course topics or laboratory experiments 2) lack of faculty inter-disciplinary expertise, 3) the resistance to the including of such topics in the senior design projects, 4) sometimes lack of students' interests, and 5) adequate laboratory equipment and devices at reasonable cost, space or new laboratory infrastructure..

2.1 Brief Description of the Developed Courses

Short description of the content, topics and motivation to develop, content and the issues to include these courses in our programs are given here.

2.1.1 Renewable Energy Course (EET 320)

Table 1: Topical Outline

Week	Topic
1	Introduction, Conventional Energy Provision Systems; Review Basic Electric and Magnetic Circuits;
2	Fundamental of Electric Power; Power System Components
3	Basic of Renewable Energy Supply; Passive Utilization of Solar Energy
4	Distributed Generation
5	Wind Resource Analysis and Assessment
6	Wind Energy Conversion Systems; Electrical Aspects of Wind Energy Conversion Systems
7	Solar Energy Resources
8	Photovoltaic Materials and PV/Solar Energy Conversion System
9	Geothermal Energy; Wave, Tide and Ocean Energy
10	Energy Storage systems; Fuel Cell Technologies and Applications
11	Hybrid Power Systems and Microgrids; Grid Integration
12	Life Cycle Analysis and Economics of Renewable Energy Systems

This is a senior undergraduate level course, designed to cover fundamentals of the renewable energy technology and distributed generation over a large spectrum of applications and to provide an introduction to the emerging technologies in these areas, as well as tools and methods used in modern industry. The course is accompanied by laboratory using hardware equipment and software simulation tools and packages, in part developed by one of the project investigators. The course covers the areas of wind, solar, geothermal, fuel cell power generation, energy storage, microgrids, grid integration, system planning and design. It also covers the modeling, analysis, and control of major RES components. This course is different from other renewable energy courses recently developed at other universities, in that it is broader and it also covers the principle of operation, and characteristics of fuel cells, energy storage devices, analysis and design of hybrid power systems and microgrids. The topics covered include the needs and benefits of distributed generation, wind and solar energy potential assessment, models of energy storage devices, power electronic interfacing, life cycle assessment and cost analysis, and grid integration issues. The benefit of such broad coverage is to give the students a comprehensive view of the various RES components. Each student picks one area to explore further by studying and presenting one or two research paper(s) to the class as well as doing an end-of-term project developing a written report and presenting the results of their work to the entire class.

The objective of this course is to present and introduce the students to various renewable energy topologies and distributed generation, their characteristics and performances[10,12-15]. Upon successfully completion of this course, the students are familiar with and knowledge of the renewable energy technologies and distributed generation. They are learning in depth wind and solar-photovoltaic energy system characteristics and performances, assessment tools and methods, controls and power electronics for such systems. Students are also expected to become familiar and to have basic knowledge of energy storage device, fuel cell and battery characteristics, models, performances and applications, grid integration of wind turbines and photovoltaic systems, design and structuring hybrid power systems and small size microgrids. The course supports the following outcomes: a) an appropriate mastery of the knowledge, techniques, skills and modern tools of their disciplines; b) an ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology; c) design a system, component, or process to meet desired needs within realistic constraints; h) understand the impact of engineering solutions in a global, economic, environmental, and societal context; and k) use techniques, skills, and tools in engineering practice. Required and recommended textbooks are: G. M. Masters, *Renewable and Efficient Electric Power Systems*, B.K. Hodge, *Alternative Energy Systems and Applications*, and instructor lecture notes.

Other alternative energy power generation sources (e.g., geothermal, marine energy, etc.) are highlighted during the course and the merits of each are given. The coverage of wind, solar-thermal and photovoltaic generation is detailed and design-oriented, while the fuel cells, energy storage devices are limited to operation principles, characteristics, and applications. As described in the previous section, the course also includes student term paper presentations and projects. A summary of the topics covered in the course is given in Table 1. The course structure, content and instructional approach, discussed in the next section of the paper are in part based on the experience gained by one of the authors, when he was involved in the design, development and teaching of similar courses, as well as in the design, test and implement of the course associated laboratory and experiments for other institutions that he used to work for[9-13].

2.1.2 Industrial Energy Systems Course (INDE 420)

Energy courses have always been the core requirement for all the concentrations within the engineering and technology programs. Over the years, our department has been reviewing the employment trends as it relates to energy and power concentration. In an introductory course for industrial energy systems and energy management, a balance between breadth and depth of coverage is needed, to provide the understanding of the structure, complexity and nature of industrial energy systems and energy management methods and tools in a single course. The benefits of the one course approach can be summarized as:

1. Course designed with a specific focus on the structure, components, operation of industrial energy systems, energy management, energy efficiency and conservation;
2. Multiple aspects of sustainability, energy efficiency and energy management are integrated throughout the course;
3. No need for cross-departmental coordination of section offerings;
4. No prerequisites, except standard physics and calculus courses.

This course was first offered in Fall 2014 quarter as a special topics course[17,18]. It is a 3-credit course with an enrollment of 28 students. The course is structured in two variants. First one was designed for a quarter-based institution. It consists of 10 lectures/units, one class project (case study), one research oriented take home tests, and a final examination. The one, designed for a semester-based institution, consisting of 15 lectures/units, two class projects/case studies, two research-oriented take home tests, and a final examination. Here, additional topics are included, while two of the existing units are expended for two weeks. Since the course is open to students with diverse technical backgrounds, emphasis is placed more on application and concepts rather than the core technical principles. It aims to train students to use methods and tools needed for identifying and designing efficient industrial energy systems, to identify the cost-optimal mix of different energy technologies to satisfy a given process energy demand and to have strong knowledge in energy management. In addition, this course also aims to familiarize the students with the application of standards and codes such as NEC, NEMA, and IEEE, used in electric and energy systems. Upon completion the course, the students have in-depth knowledge of and are familiar with the several aspects of industrial energy systems and energy management, current technologies for energy generation, inter-conversion, storage, and end-use energy processes, the basics of energy supplies, and how energy can be used more efficiently in buildings and industries. At the end of the course, students are able to identify potential energy savings, collect and analysis data to estimate energy use, and document actual achievements within an organization, develop abilities to ask critical questions and to effectively search for accurate information. Concise laboratory and project reports, clearly describing all conclusions and comments are also required during the course. This is a multidisciplinary course and in consequences we included required and recommended textbooks in the syllabus, and additional tutorials prepared by the instructor. The required and recommended references 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*.

Pedagogical approach and the unit structure deign were envisioned to make and a gradual transitions for the objectives and applications of each topics to the methods, industry tools, and advanced applications. Several examples are included in each unit from simple applications to case studies. Students were strongly encouraged work and solve in teams for home-works, assignments and case studies. Examples, problems and case studies were selected from required and recommended textbooks, PIs research, and from the references. A review of previous unit is included at the beginning of each unit. At the end of each module a short quiz is given to test students' understanding of the materials presented. Each module consists of: an introduction/unit description; 2) theoretical development, and 3) problems and case studies. The case studies are designed to reinforce and support unit/module theoretical development, to emphasize the importance of corroborating the results of measurements and data analysis with the objectives of energy management problem and application, and to expose the students to tools, methods, standards, codes and practice used in energy management and industrial energy systems. The course outline and the topics covered in the quarter-based institution are given in table 2. The additional topics and the content for semester institution are given after.

Table 2: Outline of the Industrial Energy Systems

Week	Topics
Module 1	Introduction to Industrial Energy Systems Energy, Energy Management, Techno-economic Optimization of Resources in Industrial Equipment and Energy Systems
Module 2	Fundamentals: Units: Finance, Electrical, Thermal; Standards and Policy, Energy Bills, Energy Audits, Savings Analysis, Managing Energy Resources with the Corporate and Plant Information Technology System
Module 3	Energy Conversion Equipment Characteristics; Understanding Energy Bills, Economic Analysis and Life Cost Cycle
Module 4	Lightning; Mid-term Exam Review
Module 5/ Mid-term	Heating, Ventilating, and Air Conditioning
Module 6	Co-generation, Boilers and Steam Distribution Systems; Industrial Energy System Optimization Methods and Strategies; Optimization of Size and Design Parameters; Influence on the Environment.
Module 7	Control Systems and Computers, Measurement, Verification, and Modeling
Module 8	Energy Systems Maintenance; Insulation; Economics of Energy Conversion in Industrial Energy Systems.
Module 9	Motors, Compressed Air Systems, Energy Management Systems (EMS), Data Analysis
Module 10	Smart Grid, Alternative Energy Sources, Green Buildings; Final Exam Review
Final Exam	Project Presentation

Additional units for a semester-based institution include:

Week/Module 6: Co-generation**,** Boilers and Steam Distribution Systems
Week/Module 7: Industrial Energy System Optimization Methods and Strategies; Optimization of Size and Design Parameters; Influence on the Environment.
Week/Module 10: Motors and Drives, Variable Frequency Drives, Compressed Air Systems and Fans; **Mid-term Exam**
Week/Module 11: Controls, Energy Management Systems (EMS), Data Analysis
Week/Module 13: Building Envelope, Insulation, Air Quality, Commissioning and Maintenance, Measurement and Verification, Modeling
Week/Module 14: Thermodynamics, Refrigeration, Energy Storage and Energy Optimization
Week/Module 15: Life Cycle Analysis and Assessment and Life Cost Analysis of Industrial Energy Systems

2.1.3 INDE T280 – Clean Energy and Energy Efficiency

This course INDE T280 was offered at one the institutions involved in this project as a special-topic course during the Fall quarter of 2015-2016. It is a 3-credit course with an enrollment of 6 students. INDE t280 Clean Energy and Energy Efficiency is an undergraduate special-topic course taken by pre-junior level engineering technology students, planned to be offered each fall quarter. It provides the students with the various RES experimental set-ups, such as: wind, solar, and fuel cells, investigating their contribution to the energy generation. The laboratory includes industry testing procedures and experiments. The course learning outcomes are:
1. Understand the main sources of energy, energy efficiency, and their primary applications;
2. Describe the challenges and problems associated with the use of various energy sources, including fossil fuels, with regard to future supply and the industry;
3. Evaluate economic efficiency and compare small scale energy projects using major economic measures of pay-back period, simple rate of return, net present value, and internal rate of return;
4. Evaluate manufacturing energy consumption and methods to increase energy efficiency; and
5. Relate properly their hands-on laboratory experiences to solving real world clean energy and energy efficiency engineering problems.

In order to provide an enhanced hands-on laboratory experience, the students work with real world industrial case studies associated with green energy[11,16]. Table 3 provides an overview of lecture and laboratory series in INDE t280 Clean Energy and Energy Efficiency. Teaching this course presents challenges of teaching applications rather than a discipline. In that case we could rely heavily on successful practice and then develop principles to explain those successes with clean energy and energy efficiency for green energy manufacturing. In the case of sustainable manufacturing materials, other than the real successes of solutions for energy industry, many of the current ideas have to offer convincing proof that they actually work. Therefore, instructors felt that it is important to incorporate sustainable practices concepts in the teaching it. At the end of this course, students have knowledge of sustainable technology and sustainability related to manufacturing materials, being able to handle specific problems concerning sustainability and manufacturing materials. The class is taught for 10 weekly lectures, 3-hour each, in a normal quarter or can be adapted to summer sessions. Lectures are considered to be classes that are given completely by the instructor or a specialist of the topic being taught. The last section of a lecture is focusing on the design of the different systems, producing energy from renewable resources. This allows the students to understand how these products are made and manufactured. The class is evaluated through two exams, assessing the level of the student understanding of the course materials. The course is broken down into 10 modules, as shown in table 3. The course contains comprehensive discussions on the sustainability, metrics, general design processes, and challenges. The current approaches to design, manufacturing, and disposal are discussed in the context of examples and case studies from various sectors, providing basis for what and how to consider when designing energy products, processes, and systems to contribute to furthering sustainability. The fundamental engineering design topics to be addressed include toxicity and benign alternatives, pollution prevention and source reduction, separations and disassembly, material and energy efficiencies and flows, systems analysis, and life cycle assessment and design, management, and analysis. Students tackle current energy system design challenges in a series of class exercises and a final design project.

Table 3: Overview of lecture and laboratory series

Week	Topic	Lab Experiment
1	Introduction to energy systems and resources, sustainability & the industry	No Lab
2	Solar - PV and Solar – thermal Systems	Solar Cell Lab
3	Wind Energy Conversion	Wind Power Lab
4	Fuel Cells	
5	Hybrid Power Systems (PV-Fuel Cell-Wind)	Hybrid Energy Lab
	Midterm Exam	
6	Green energy manufacturing project A:	
7	LCA Simulation (Paper clip)	LCA simulation 1
	Green energy manufacturing project B:	
8	LCA Simulation (solar cell, fuel cell, wind)	LCA simulation 2
9	Industrial Energy Efficiency	Energy Efficiency Lab
10	Thermal Energy Imagining, Energy Audit	Energy Management Lab
11	Final Exam	

3. Projects with Renewable and Sustainability Context

Senior or capstone design courses fill a critically important role in the engineering and technology curriculum, forming a bridge between school and the workplace, being extensively discussed in the literature[12-18]. These courses bring to the forefront many of the ABET outcomes such as lifelong learning, design, teamwork, and contemporary issues[11]. On the other hand, even the sustainability is included in ABET's description of considerations for design is not too often incorporated into student projects. For the past years, our focus has been shifted towards incorporating more renewable energy, sustainability and green manufacturing topics in senior design course sequence, and in adding research projects on these topics in several upper division courses, such as power electronics, energy conversion or power systems. Our capstone course is a three-term sequence. In the first term, we assign to our students the project topics related to renewable energy, power systems, or green energy manufacturing. These projects provide multidisciplinary collaboration and valuable hands-on experience to the students. In addition to useful lessons on teamwork and project management, they also provide working demonstration of green energy systems. The PIs and Co-PIs have continuously advised senior project design courses at both participating institutions towards incorporating renewable energy and energy efficiency topics since the begging of the project. Based on the project design course sequence in the first quarter we assigned our students with the project topics related to renewable energy, power systems or other engineering topics. These projects are indeed a good example of multi-disciplinary cooperation of different engineering disciplines.

As we pointed out, for the last four years our focus shifted towards incorporating renewable energy concepts in our senior design projects[26-30,37-45]. At very begging of the fall quarter (section I) instructor in charge with the Senior Design Project courses is giving the requirements for the projects. At the end of spring quarter (section III), each team demonstrates the finished projects to the entire class, while a written report summarizing the project status and structure is required each quarter, as part our senior project design course. This process synthesizes all of the basic materials in the core courses and can also be used as part of the requirements. Two oral presentation one in Fall quarter, emphasizing on the project rationales and the other in Spring quarter focusing on the project description and design are also part of the course requirements. Examples of the renewable energy senior design projects included are:

1. Micro Direct Methanol Fuel Cell (2014)
3. Green Energy Solar Collectors (2014)
4. Solar Tracking – Dual Axis (2014)
5. Design and Implementation of a Micro-Wind Turbine (2014)
6. A Digitally Controlled and Portable Photovoltaic Power Source (2014)
7. Design and Test of a Solar-Powered Car (2015)
8. Automated Green Energy House Solar Heating (2015)
9. Hybrid Wind and Solar Powered Outdoor Area Lighting (2015)
10. Solar Powered Rain Alarm (2015)
11. Micro-fluidic Direct Methanol Fuel Cell (2015)

Students are required to analyze, design, simulate, and build a completely functional system by the end-of-term project. The project goals are to explore and enhance student understanding of the fundamental concept of design-for-environment and hands-on learning of green energy. Senior Design course sequence is organized following the ABET guideline for capstone and/or senior project design courses[11]. All students have to work in teams of three or four, considered an optimum team size. A team of two may result in distress in cases where one of the students was not able to do his or her share of the work, while for teams larger than four may have difficulties to choose projects which were challenging enough for such a big group of students and still could be finished within three-quarter timeframe. Students are required to analyze, design, simulate, and build a functional system by the end-of-term project.

4. Lessons Learned and Student Responses

The courses were designed with the following objectives. 1) We are facing several environmental challenges. Emission of large amount of greenhouse gases, climate changes, extinction of species at alarming rates, rapid depletion of natural resources, increasing world population and energy demands, desert area expansion, and deforestation are few from a long list of problems. These courses should expose students to such major issues. 2) An important objective is to show various information technologies, systems and their operations that can help in creating and sustaining green economy. 3) Bring out the needs of every individual and society involvement in solving such issue. 4) Conduct experiments, record and analyze data. 5) Provide opportunity to think critically about environmental aspects and communicate effectively. 6) Give opportunity to develop writing and presentation skills[12-18]. A search for a textbook for these courses found that no one textbook covered all the topics included in any of these three courses, a textbook includes often, only a subset of the intended topics. At the end of the semester or quarter, students were asked to give feedback on the textbooks and instructor materials. Some students conveyed that not all information or topics included are easy to comprehend. Overall, the students were positive with the topics covered.

Each of the course syllabus stated that everyone must participate in every forum, take into account various aspects, think critically and express his or her views and opinions openly without fear or reservation. Each student should also respond to others' views and opinions amicably without using unfriendly expressions. Students were encouraged to think and analyze taking into account various factors while expressing his or her views as well as responding to other views. The syllabus had a detailed description of the course including weekly readings, project and homework dues dates, exam dates, course objectives, grading method, instructor contact information, etc. During the first week, students must read the syllabus, and acknowledge the fact that they read it and understood what is expected of them. In this forum, students were given opportunity to introduce themselves to classmates and the instructor. In addition, they can state their expectations from the course.

Table 4: Informal student assessment

Questionnaire		Score
Q1	Are the course topics challenging and interesting?	
Q2	Have you learn more than expected with the course?	
Q3	A team project will be useful to you?	
Q4	It will useful to add a laboratory component to future INDE 420 (4 credits version of this course)?	
Q5	Please, provide an overall evaluation of the course.	

Each student has to complete projects in each of the new courses. Projects were created with the objective, among others to develop student writing skills. A significant number of students mentioned that they never wrote a technical paper and wanted to know what should be in it. Instructors suggested and illustrated to list the references as a numbered list and use the numbers to cite at appropriate places in the body of the paper. A significant percentage of students did not know that the reference section should have only those entries that are referenced in the body of the paper. Overall, students did well in each of the projects. They understood the need and benefits of full disclosure by the manufacturers so that consumers can make an informed choice of what they buy and dispose. Student evaluation done at the end of the semester or quarter, processed after grades were submitted showed that the courses were well received. In these courses students learned about industrial environment, RES technologies, energy conservation and use, standards, and codes used in energy industries. These courses could be improved in many ways, in particular presenting relevant information and topics, tools and methods used in modern industries, projects and case studies. There were between 6 and 28 students enrolled in each of these courses. Students are mostly form engineering and engineering technology programs, but also there were students form physics, chemistry and even business programs. Students' feedback and evaluation of each the courses have been quite good. The students also expressed their desire to have more projects involving software packages that are used in modern energy industry. Table 4 contains the questionnaire for the informal course evaluation conducted at the end of each term or semester. Students are requested to answer on a five point scale: 1-very poor, 2-poor, 3-satisactory, 4-good and 5-very good to an anonymous questionnaire. Results of the students' evaluations were summarized in table 5. The student participation in these surveys were good, similar or above participation in the university conventional end of term evaluations. Overall evaluations and students' feedback have been quite positive.

Table 5: Summary of student evaluations

Question	EET 320 Fall 2012	EET 320 Spring 2013	EET 320 Summer 2014	INDE 420 Fall 2014
Q1	4.2	3.9	4.0	3.5
Q2	3.8	4.4	4.2	3.3
Q3	3.7	4.1	4.1	3.2
Q4	3.8	3.7	4.3	3.4
Q5	4.2	3.9	4.3	3.5
Student Response	70%	67%	63&	75%

5. Summary and Conclusions

This paper provides an overview of steps to initiate and implement green engineering, renewable energy, sustainable and green design concepts and topics into our engineering and engineering technology programs. These efforts are part of project sponsored by the Department of Education (2013-2017). The project includes the development of new courses, restructuring senior design project course sequences, inclusions of relevant projects in these areas in existing upper level courses. While the present achievements of this project are significant, 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 energy engineering, green design, sustainability and energy management contexts have on the others aspects on engineering practice and education. An important aspects of our project, consisted of the course adaptations and restructuring to include the new concepts into the old curricula, developing new courses and laboratory experiments, proposing design projects with such design topics, not only into the senior design project course sequence but also into upper level courses. The new courses are offered as senior or junior electives and cross-listed in the both engineering and engineering technology curricula. We strongly believe that by providing energy management, industrial energy, green design, manufacturing and energy-related courses on undergraduate level have potential to increase students have the opportunity of exploring multiple facets of green energy, and 3) the collaborative the students' interests in engineering careers. We also strongly believe that the inclusion energy related projects are beneficial to all our students and our programs. Assessments conducted all over the project duration show positive student feedbacks and interests, as well as very good and useful comments and suggestions made by the students. Lessons learned are available for interested parties, instructors or researchers. Feedback and suggestions from other instructors and educators are highly appreciated.

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