A Renewable Energy Specialization in an Electronics Engineering Technology Curriculum

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A Renewable Energy Specialization
Nested in an Electronics Engineering Technology Curriculum

Corporations facing the challenge of developing energy-efficient, sustainable, and environmentally friendly products and power sources are seeking engineers and technologists with expanded skill sets to meet these demands. In order to address this need, a renewable energy specialization within an already existing curriculum in Electronics Engineering Technology (EET) was developed. The goals of this specialization are to give students a contemporary option of study to attract those that might otherwise not be interested in engineering technology, to increase program persistence and completion, to provide campus-based and online delivery options for the education, and to better prepare students interested in careers in power and renewable energy industries. The renewable energy curriculum is offered campus-based, which accredited by the Engineering Technology Accreditation Commission (ETAC) of ABET, and its online equivalent, which has not sought ETAC of ABET accreditation to date.

The curriculum builds on the fundamentals of biology, chemistry, physics, electronics, environmental science, and mathematics required as prerequisites to advance the student into focused coursework in environmental economics, conservation principles, sustainability, environmental sociology, power transmission and generation, alternative energy, power electronics, and renewable energy management. This paper presents the formal structure of the overall curriculum, the sequence of courses within the renewable energy specialization, a general description of the content within each specialization specific course, and a mapping of the program outcomes to an assessment strategy. First graduates are expected to complete the specialization by the end of Spring 2014, when an analysis and evaluation of direct assessment data will be conducted and reviewed.

Introduction

Not all members of society support movements toward renewable energy and green technology or the scientific findings that claim environmental damage as a result industrial practice, energy production, or electronics waste. Regardless, industry and governments are increasingly pursuing green technology and sustainability[1], and there is a growing evidence for the need for technical specialists versed in renewable power systems[2].

This paper presents the creation of a renewable energy specialization within an already existing curriculum in Electronics Engineering Technology (EET) to address this need for green education. This interdisciplinary option of study was established to increase program interest for those otherwise not interested in electronics, improve persistence and completion by providing an alternate pathway of study for those potentially disenchanted with traditional electronics curricula, and to prepare students that desired careers in power and renewable energy fields. This track was developed for campus-based and online delivery, and first began accepting freshman and transfer students into the program during the Spring of 2011.

Curriculum Design

The renewable energy technology track design took into consideration many factors. First, programmatic accreditation requirements as specified by the Engineering Technology Commission (ETAC) were upheld[3]. Secondly, adjustments to the program of study were required to re-introduce fundamental power-related coursework into the EET program, as the content had shifted in the past decade toward technology advancements in embedded, network and communications systems. There was also an effort to adjust course load balance to strengthen student outcomes with respect to societal and global awareness. Finally, the design was guided in part using competency models developed by the Employment and Training Administration (ETA) in collaboration with the Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), the National Renewable Energy Laboratories (NREL), and other industry associations. These are fluid models meant to prepare a workforce diverse in energy technology and environmental protection[4].

The renewable energy engineering track curriculum structure is described below. Alterations to the fundamental core requirements in electronics engineering technology were made to allow for some formal coverage of biology, chemistry, environmental science, and conservation principles, in addition to the traditional physics, electronics, and mathematics prerequisite knowledge coursework. This then allowed for advanced studies in the areas of environmental economics, sustainability, environmental sociology, and power transmission, generation of energy, power electronics and renewable energy management. Figure 1.0 shows a typical plan of study.

Standard Mathematics and Science Requirements

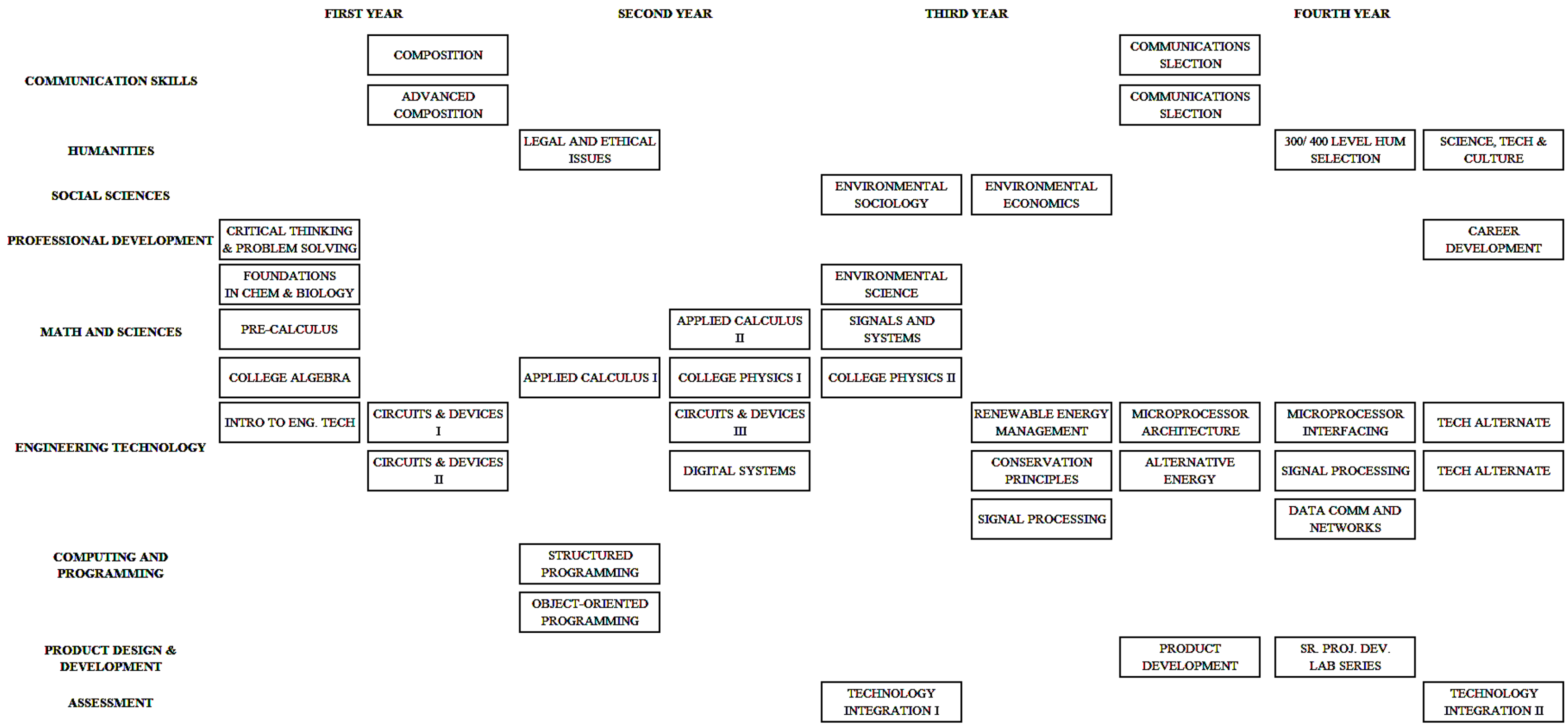
The following requirements in math and science are the same for the renewable energy track option and the standard electronics engineering technology curriculum. One term of pre-calculus, followed by two terms of calculus, which provide a brief introduction to differential equations, is required. A 300-level course in Signals and Systems is then taken to support upper term power engineering technology study. Finally, critical topics to alternative energy technologies topics such as Newtonian physics, electricity, thermodynamics, and electromagnetism are studies across two calculus-based physics courses.

Foundations in Analog and Digital Electronics

An introductory course is taken where fundamentals of digital and analog electronics, circuit simulation, and use of test equipment are first presented. Campus-based and online students purchase a kit that provides them all the general materials (wire, breadboards, components, tools, etc.) necessary to laboratory work throughout their curriculum. Online students are further provisioned with an oscilloscope, digital multi-meter, power supply, and signal generator, whereas campus-based students have access to facilities with workbenches replete with test equipment.

A three course sequence in fundamental electronics is taken by all electronics engineering technology students. Reinforcement of test equipment and circuit simulation, DC, AC, and device fundamentals are all covered. The device course introduces some basic power topics such

Figure 1.0 Typical Plan of Study for the REET Option



as amplification, power devices, and transformers. A final course covers the basic design and analysis of digital circuits, bases for all computer systems and virtually all other electronic
systems in use today.

Five additional courses are required by all majors to complete their fundamentals coverage. Structured and object oriented programing, assembly language, microprocessor architecture and peripheral control, and embedded microprocessor programming are introduced. These are important pre-requisite areas of study for the for the renewable energy students later when power control and monitoring topics, such as smart meters and grid technologies, are covered.

Science Basics

Due to limited space in the program of study, three focused science courses were adopted to address needs in the curriculum. A 100-level algebra-based, hybrid course in chemistry and biology was adopted to survey basic chemical and biological concepts that would later support the understanding of many alternative and renewable energy technologies, such biofuel sources and microbial fuel cells. Environmental Science, a 200-level interdisciplinary science course, is taken. This course integrates natural and social science concepts to explore the interrelatedness of living things. Environmental issues, problems and possible solutions are explored. Topics include sustainability, ecosystems, biodiversity, population dynamics, natural resources, waste management, energy efficiency and pollution control, as well as associated ethics and politics. Finally, a calculus-based course in conservation principles has been adopted to allow for expanded study in Newtonian physics, electricity, thermodynamics, and electromagnetism, these topics being especially critical to the understanding of many renewable and alternative energy technologies.

The conservation principles course is based in the conservation laws of mass, energy, charge and momentum. Students apply fundamental engineering concepts to problems in statics, dynamics, fluid mechanics, electrical circuits and thermodynamics. In the lab, students model systems involving alternative energy deployment and industrial process controls.

Upper-division Coursework in Sustainability, Energy, and Power

Students in the renewable energy option are required to take two social studies courses. One is a 300-level course in environmental sociology; the other is a 400-level course in environmental economics. Students in the standard electronics engineering technology curriculum may also elect to take these courses as part of the fulfillment of general education requirements.

The environmental sociology course explores environmental issues as perceived by society, and addresses cultural norms, ideologies, beliefs and economic and gender-related factors that affect finding and providing sustainable solutions to environmental problems. Through discussions of research, problem-solving projects and presentations, students learn to identify causes of environmental problems and apply practical solutions to particular cases. Environmental economics introduces the concept of economic model application to the environment (air, water, land). Systems that interface with the environment, processes that use materials from the environment, and waste products of systems and processes are analyzed with economic models providing insight into managing businesses and our lives in a sustainable fashion.

Renewable and alternative energy technologies are formally presented in two 300-level courses. The first is a 300-level business management course - Renewable Energy: Science, Technology and Management. In this course, the science and technology behind renewable energy technology are surveyed, while considering business decisions required to invest in and manage systems using this technology. Among others, solar technologies, fuels synthesized from biomass, hydrogen and wind are explored. Students leverage RETScreen® Software Suite (www.retscreen.net) to conduct case studies.

The second course is an advanced technical course that draws on all previous course work in science, math and engineering technology called Introduction to Alternative Energy Technologies. Here, renewable and alternative energy technology concepts are covered in depth. Topics include photovoltaics, solar thermal systems, wind power, fuel cells, hydroelectricity, the smart grid, alternative fuels, geothermal power, waste heat and biofuels. The socioeconomic, environmental, political and regulatory issues with these technical concepts are considered in parallel. Lab exercises involve simple modeling and problem solving using MATLAB® (www.mathworks.com) to explore key aspects of alternative power sources and sustainable energy solutions that meet today's power demands.

Two 400-level power courses are offered as technical alternates for the renewable energy track students. These courses are also technical elective options in the standard electronics engineering technology program of study. The power electronics course presents in the context and application of alternative energy topics such as, power switching, rectifiers, AC-DC and DC-DC converters, inverters and motor drives. Power semiconductor devices, thermal management, efficiency and power electronics applications are emphasized. Lab projects involve simulation and construction of power electronic circuits needed to convert power derived from both conventional systems and alternative energy sources such as solar and wind. Students are given the option to use the technical alternates for internship experience.

The second class presents electric machines and power systems, with emphasis on renewable energy applications. Topics include three phase circuits, power factor correction, transformers, synchronous machines, DC motors, induction motors, power system transmission and distribution and power flow studies. Lab work requires students to both simulate and construct basic electric machine concepts needed for power transmission.

All senior engineering technology students undertake a thirty two week long senior project sequence with focus on their chosen field of study. The sequence starts with a product development course that examine product life cycle from initial concept through manufacturing. Students establish teams to develop a senior project, while the coursework addresses project management, total quality management, codes and standards, prototype development, reliability, and product testing. Teams prepare a written proposal for the senior project and make an oral presentation to class. The teams are often interdisciplinary in nature with a mix of renewable energy track, computer, and electronics engineering technology majors working together. To ensure the appropriate experience is provided to students with different areas of emphasis, the proposals are reviewed and approved to ensure that the appropriate program specific outcomes are met in this integrated technology experience. These outcomes are addressed below in Table 3.0.

There is also a humanities capstone course that all students complete in their senior year called Technology, Society, and Culture. In this course, the relationship between society and technology is investigated through reading, reflection, research and reports. The course identifies conditions that have promoted technological development and assesses the social, political, environmental, cultural and economic effects of current technology. Discussion and oral and written reports draw together students' prior learning in a specialty area and general education courses. Renewable energy students are encouraged to focus on contemporary issues concerning energy production, management, and sustainability.

Program Educational Objectives, Student Outcomes, and Assessment Strategies

Program Educational Objectives

Program Educational Objectives (PEOs) are those attributes graduates are expected to attain within a few years of graduation. The PEOs for the electronics engineering technology education have been written to meet the needs of and have been reviewed by the stakeholders of the program are listed in Table 1.0. These statements are particularly board and adaptable to any electronics engineering technology field, such as renewable energy and green consumer electronics.

Table 1.0 Program Education Objectives Adopted for The Renewable Energy Specialization in Electronics Engineering Technology.

Objective	Description
PEO #1	Finding employment in an electronics technology-related position with appropriate title and compensation
PEO #2	Achieving a successful professional career
PEO #3	Adapting to change through continuous personal and professional development

Student Outcome

The skills, knowledge, and behaviors expected of electronics students at the time of graduation are provided in Table 2.0. These student outcomes (SOs), listed A through L have been written to match ETAC of ABET's General Criterion 3a-k and Program Specific criteria for Electronics Engineering Technology Programs. Table 3.0 presents specific attributes expected of students completing the renewable energy specialization. These attributes are a subset of the Program Criteria found in ABET's Program Specific accreditation criteria for EET programs[3]. Table 4.0 summarizes the major assessment tools leveraged to measure attainment of SOs.

Programmatic Accreditation

Many of the campus-based offerings have had a long history of accreditation with ABET Inc., presently through the Engineering Technology Commission (ETAC). As ETAC of ABET requires separate review of each engineering technology program and/or pathway to graduation in both online and physical delivery modalities, the online format and few physical locations are not accredited by ETAC of ABET. Further, the renewable energy engineering technology track is an elected option of study through the electronics engineering technology curriculum, thus requiring review by ABET as well. For those physical locations that have ETAC of ABET accredited programs in electronics engineering technology, the renewable energy technology track option is included as pathway to graduation under this accreditation.

Table 2.0 Student Outcomes Mapped to PEOs and ABET Criteria
Rating: 0 = No applicability; 1 = Low applicability; 2 = Medium applicability; 3 = High applicability

PEO #1	PEO #2	PEO #3	Student Outcome (SO)	Description	ABET Criteria
3	2	1	**A**	An ability to select and apply the knowledge, techniques, skills, and modern tools of their disciplines to broadly defined engineering technology activities.	General Criteria - Criterion 3a
3	1	1	**B**	An ability to select and apply knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures and methodologies.	General Criteria - Criterion 3b
3	1	2	**C**	An ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes.	General Criteria - Criterion 3c
3	2	2	**D**	An ability to design systems, components, or processes for broadly defined engineering technology problems appropriate to program educational objectives.	General Criteria - Criterion 3d
2	3	1	**E**	An ability to function effectively as a member or leader on a technical team.	General Criteria - Criterion 3e
3	1	1	**F**	An ability to identify, analyze, and solve broadly defined engineering technology problems.	General Criteria - Criterion 3f
2	3	2	**G**	An ability to communicate effectively regarding broadly defined engineering technology activities.	General Criteria - Criterion 3g
1	3	3	**H**	An understanding of the need for and an ability to engage in self-directed continuing professional development.	General Criteria - Criterion 3h
1	3	3	**I**	An understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity.	General Criteria - Criterion 3i
1	2	3	**J**	Knowledge of the impact of engineering technology solutions in a societal and global context.	General Criteria - Criterion 3j
1	3	2	**K**	A commitment to quality, timeliness, and continuous improvement.	General Criteria - Criterion 3k
3	2	2	**L**	An appropriate level of achievement of the body of knowledge required by the Institute of Electrical and Electronics Engineers (IEEE).	Program Specific Criteria

Table 3.0 Delineation of Student Outcome L

Subset Criteria for Outcome L	Description
L1	Demonstrate knowledge and application of circuit analysis and design, computer programming, associated software, analog and digital electronics, and microcomputers, and engineering standards to the building, testing, operation, and maintenance of **electrical/electronic(s) systems.**
L2	Demonstrate knowledge and application of physics or chemistry to electrical/electronic(s) circuits in a rigorous mathematical environment at or above the level of algebra and trigonometry.
L3	Demonstrate the ability to utilize statistics/probability, transform methods, discrete mathematics, or applied differential equations **in support of power and energy systems**
L4	Demonstrate the ability to apply **project management techniques to power and energy systems**
L5	Analyze, design, and implement **power and energy systems**

Table 4.0 Assessment Strategies

Assessment	Description / Summary
Formative Assessment Exam	Examination administered after 200 –level technical courses have been completed
Summative Assessment Exam	Examination of all technical coursework to address achievement of Student Outcome A; and Program Specific Outcomes (L1 - L5)
Senior Project	This is an integrated curriculum experience used to assess Student Outcomes B to K and L1 to L5
Humanities Capstone	This is an integrated curriculum experience used to indirectly assess Student Outcomes E to K

Continuous Improvement and Future Work

The graduates from this specialization are expected to complete their program of study by the end of Spring 2014, when an analysis of initial program assessment data will be conducted and reviewed. In 2012, faculty and engineering technology administration have re-reviewed the applicability and relevance of the program educational objectives and student outcomes to the curriculum. Although the PEOs and SOs are generally viewed to be acceptable, there are plans to improve and update them by applying Conceive, Design, Implement, and Operate (CDIO) standards (www.CDIO.org) with a subsequent re-mapping of the curriculum. The CDIO model will help enhance the sustainable product life cycle curriculum design already in place.

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