AC 2009-689: CURRICULUM CHANGES RESULTING IN A NEW B.S. IN RENEWABLE ENERGY ENGINEERING

Robert Bass, Oregon Institute of Technology

Dr. Robert Bass is an assistant professor at the Oregon Institute of Technology, where he directs the Renewable Energy Engineering bachelors degree program (BSREE), the first engineering program of its kind in North America. He is also a member of the Oregon Renewable Energy Center, OREC, where he participates in undergraduate research projects concerning microhydro power generation, solar thermal absorption chillers and electrochemical production of hydrogen.

In addition to running the BSREE program, Dr. Bass also specializes in teaching courses in electrochemistry, electromechanical energy conversion, electric power, circuit fundamentals, photovoltaic systems, fuel cells, solid-state materials and power electronics.

Dr. Bass received his Doctorate in Electrical Engineering from the University of Virginia in 2004. His dissertation research centered on sub-micron semiconductor device fabrication methods, submillimeter-wave and quasi-optical circuit design, and unique fabrication technologies for superconducting terahertz heterodyne receivers. He got into renewable energy via good fortune.

Thomas White, Oregon Institute of Technology

Tom White comes to the OIT Renewable Energy Engineering faculty after 30 years working in industry as a manufacturing engineer, renewable energy projects manager, technical writer and course developer, business process consultant, and – most recently – the lead engineer at a design firm, where he managed a small group of talented young engineers who model and analyze energy use in “green buildings.”

Tom has previously taught as an adjunct at Portland State and the University of Phoenix. His interests lie in teaching core engineering courses including statics, thermodynamics, heat transfer, fluid mechanics, and technical writing, as well as advanced courses in renewable energy applications, building energy systems, and the analysis and design of “green” buildings.

Tom is a licensed professional engineer with LEED accreditation, and earned his bachelor’s degree at Santa Clara University and his master’s degree at Portland State University, both in mechanical engineering. Tom also holds a bachelor’s degree in biological sciences from the University of California, Santa Barbara.

As a working engineering, Tom has put an emphasis on hiring and developing interns, mentoring his team, and promoting their services to architects and business owners. Tom would like to use his teaching platform to arrange internships for motivated students. In his role as team leader, and now teacher, Tom feels he has an enviable opportunity to guide and support the next generation of engineers. It is the OIT graduates who will inherit the challenge of creating a more sustainable future, contributing their creativity to solve the triple problem of climate change, peak oil, and energy independence.

Curriculum Changes Resulting in a New Bachelors of Science in Renewable Energy Engineering

Abstract

In 2005, the Oregon Institute of Technology (OIT) began offering its new Bachelors of Science in Renewable Energy Systems program (BSRES) at its satellite campus in Portland, Oregon. The BSRES degree was the first of its kind in North America, and it was created to prepare graduates for careers in the various fields associated with renewable energy. These include, but are not limited to, energy management, energy auditing, energy systems planning, energy economics, energy policy and development, carbon accounting and reduction, and energy-related research, as stated in OIT's 2005-2006 catalogue.

In 2008, however, the BSRES degree was discontinued and replaced by the Bachelors of Science in Renewable Energy Engineering (BSREE). Analysis of the market place and observed growth in career options across the renewable energy fields revealed significant opportunities for graduates with a solid energy engineering education. This paper discusses these and other motivating factors that convinced the Oregon Institute of Technology to change track and begin offering the Bachelors of Science in Renewable Energy Engineering, another first-of-its-kind in North America. The paper also discusses the program objectives, program outcomes, curriculum, and the current enrollment status of the program.

Introduction

In 2005, the Oregon Institute of Technology introduced the nation's first Bachelor of Science in Renewable Energy Systems (BSRES) at its Portland campus. Within two years, the BSRES program saw an increase in enrollment from 4 students to 55. By Fall 2007, students from more than twenty states had moved to Oregon specifically to earn the BSRES degree. OIT Portland is a commuter branch campus.

In 2008, however, the BSRES degree was discontinued and replaced by the Bachelors of Science in Renewable Energy Engineering (BSREE). Analysis of the market place and observed growth in career options across the renewable energy fields revealed significant opportunities for graduates with a solid energy engineering education. By design, the original BSRES program was built atop a firm engineering foundation, and the curriculum could generally be described as near engineering-level. But the title of the degree, Renewable Energy Systems, a dearth of 300-level mathematics coursework and the absence of several key engineering fundamentals courses prevented the degree from being considered a full engineering degree, particularly one that could be accredited as an ABET EAC program. By stating engineering as a principle programmatic focus, the career potential for graduates expanded beyond those previously stated to also include engineering-related career paths such as electrochemical systems engineering, energy systems design engineering, building systems engineering and modeling, hydronics engineering, power electronics engineering, HVAC engineering, and power systems engineering.

We anticipate that most of the BSREE graduates will enter energy engineering careers. Therefore, it is imperative that these students be provided with a smooth pathway towards Professional Engineer (PE) licensure. In the State of Oregon, only graduates of ABET-accredited engineering (EAC) or engineering technology (TAC) programs may sit for the Fundamentals of Engineering exam. Considering that many engineering graduates never seek professional licensure, this may at first glance not appear to be a serious concern. But, after analyzing the career opportunities for our graduates, it became evident that vertical career mobility in two major renewable energy engineering-related industries would be greatly limited if a graduate was not able to earn licensure as a Professional Engineer. These, broadly, are the electric power industry, and what may best be described as the "green building" industry, a term attributed to engineering and design-build architecture firms focused on LEED-related building projects. We estimate that around a quarter to a third of our graduates will seek careers in these two industries. Consequently, we decided to change the original BSRES degree into one that would be eligible for ABET EAC accreditation, the BSREE degree.

We anticipate BSREE program graduates will enter energy engineering careers as power engineers, PV/semiconductor processing engineers, facilities and energy managers, energy system integration engineers, HVAC and hydronics engineers, design and modeling engineers for net-zero energy buildings, LEED accredited professionals (AP), biofuels plant and operations engineers, energy systems control engineers, power electronics engineers, utility program managers, as well as renewable energy planners and policy makers. Graduates of the program will be able to pursue a wide range of career opportunities, not only within the emerging fields of renewable energy, but within more traditional areas of energy engineering as well.[1] Without a mechanism for obtaining professional licensure, these graduates would either not be able to advance in their careers or they would not find employment in these fields to begin with. Our survey of the renewable energy industry cluster in the Pacific Northwest convinced us that an engineering degree, the BSREE degree, was the only suitable option for our students.

Industry Cluster Analysis

Renewable energy resources are attracting considerable investment as concerns surrounding the stability of energy supply, increased energy costs and climate change have continued to challenge the status-quo of national and state energy policies. As a result, the various renewable energy industries are growing rapidly, resulting in a great need for qualified energy engineering expertise. Significantly, in Oregon aggressive policies from the Governor's office have spurred the development of sizeable renewables-related industries, particularly wind power, solar, and energy-efficient buildings. For example, some companies, such as Vestas Wind Systems (Denmark), REpower (Germany) and Iberdrola (Spain, formerly PPM), have chosen to set up their North American headquarters in Oregon, while other renewable industry companies are developing a strong presence in Oregon.

For the sake of demonstrating employment potential for graduates earning the BSREE degree, the cluster of renewable energy industries in Oregon and the Pacific Northwest may be divided into three main categories: wind power, solar (PV and thermal) and energy-efficient ("Green") buildings. This analysis does not discuss employment potential in the traditional power

engineering sector, which we also see as significant, nor does it discuss other renewable energy industries such as biofuels, wave power, fuel cells and power electronics, all of which also have a significant presence in the Pacific Northwest.

Wind Power

According to the American Wind Energy Association (AWEA), installed capacity of wind power in the Pacific Northwest (Oregon and Washington) totaled 2.3GW as of November, 2008, with another 420MW under construction, represent a 210% increase on 2005 figures[2]. The electricity generating potential by wind in Oregon is projected at 70 million MWhr/year[3].

The wind resource potential in Oregon, along with a political climate conducive towards wind farm development, have persuaded Vestas Americas, REpower and Iberdrola to locate their North American Headquarters in Portland. PacifiCorp, PGE, Florida Power & Light, Babcock & Brown, Energy Northwest, Puget Sound Energy and various other consortia maintain or are installing wind power facilities in the Pacific Northwest. AWEA projects an addition 8.5GW of wind capacity will be installed in the U.S. in 2008-2009, atop the current U.S. installed capacity of 21.0GW. In Oregon, all of the utility-scale installed capacity is occurring east of the Cascades, bringing economic growth to rural parts of the state that have been in decline.

Solar, Manufacturing and System Design

Industry interests in developing solar power in Oregon are also evident by the decisions of companies to locate facilities in the state. SolarWorld, a German manufacturer of photovoltaic cells, plans to invest $397 million in a new 500MW plant in Hillsboro, creating 1,100 new jobs . Solaicx, a Santa Clara-based photovoltaics manufacture announced it too will invest in new production in Oregon, investing $52 million and creating around 100 new jobs . Other players in the solar industry in Oregon include Peak Sun Solar, Sanyo, XsunX and SpectraWatt (an Intel spin-off).

The Oregon state legislature has acted aggressively to promote solar power. In 2007, the legislature passed bills mandating a 25% renewable energy portfolio standard (RES)[4], an increase in the business energy tax credit (BETC) to 50%, an increase in the residential energy tax credit (RETC) to $6000 per photovoltaic system[5], a "Solar on Public Buildings" initiative[6], a "Solar Teamwork" bill[7], and a modification to the state kicker fund to support BETC.[8] These legislative acts are designed to spur investment in solar energy in Oregon, and have been sited as motivations for the moves made by SolarWorld, Solaicx, Peak Sun Solar and others. Federal incentives have also played a significant role in promoting renewable energy, particularly photovoltaics. The federal residential renewable energy tax credit for photovoltaics was changed in 2008 from 30% with a $2000 cap to 30% without a cap, with an eight year extension.[9]

Energy-Efficient ("Green") Buildings

The Pacific Northwest, and Oregon in particular, might well be considered the birthplace of the sustainability movement. In recent years, there has been a groundswell of interest in "green" building design. Most prominent is the advent of the LEED system—Leadership in Energy and Environmental Design. Oregon has more LEED-certified buildings per capita than any other state, and the interest among architect and engineering design firms has been intense and very focused, with the rate of registered LEED projects growing significantly since 2000. The green

building movement is more than a trend; it is a new paradigm for creating a sustainable built environment.

“Green” or sustainable design requires engineers who understand energy conversion principles and applications. Preparation includes education across many disciplines, especially training that integrates the traditional fields of architecture, mechanical and electrical engineering, systems thinking, economics, and environmental sciences.

Since 2000, the demand in the green buildings field for engineers who can work as energy modelers, consultants, renewable systems analysts, and project managers has grown unabated, and continues to expand steadily. New LEED projects, for example, require energy modeling to analyze alternative designs with the goal of creating very energy-efficient buildings.

Energy engineers are employed in consulting engineering design firms, architecture firms, federal, state, and local agencies that support sustainability programs, and companies that manufacturer efficient building systems, such as controls and HVAC equipment, and building developers who have a commitment to sustainable practices and principles. With the recent Oregon 2025 legislation to develop renewable energy resources, there will be a redoubled interest in ways to integrate renewable energy systems into buildings. The focus of OIT graduates will be applications of geothermal heating and cooling, photovoltaics, solar heating, wind power, and energy-efficient HVAC systems and architecture.

Review of Similar Programs

The BSREE degree program, as the name states, is an energy engineering bachelors program. In the United States, energy engineering is an under-served engineering field. Pisupati notes fifteen programs with foci on energy.[10] Of these, only seven are in the U.S, and only four of those offer bachelors degrees with the phrase "energy engineering" in the title; Stanford University's BS degree in Energy Resources Engineering; Penn State's BS in Energy Engineering; the University of Texas' BS in Mechanical and Energy Engineering; and OIT's BS in Renewable Energy Engineering. Since Pisupati's paper was presented in June 2008, Indiana Tech has started a BS in Energy Engineering, and IUPUI has proposed a program, which may begin in Fall 2009. Of these only OIT's BSREE program focuses on a broad range of renewable energy engineering topics. The dearth of energy engineering programs, and the rising need for engineers in the aforementioned cluster were two other motivating factors behind OIT's decision to convert the BSRES program into a full-fledge, engineering program.

As a metric for how underserved energy engineering is in the United States, consider ABET does not list "energy engineering," or any permutation thereof, as a separate discipline.[11] Noteworthy, ABET does accommodate narrow engineering disciplines, such as petroleum (17 accredited programs), architectural (17), geological (14), mining (13), naval architecture and marine (9), metallurgical (9), and ceramic (3) engineering.

BSREE Program Description

The BSREE curriculum, shown in Table 1, combines the energy-related aspects of electrical engineering (electric power, solid-state devices, power electronics) and mechanical engineering (statics, fluid mechanics, thermodynamics, heat transfer) to create an engineering foundation upon which upper-division renewable energy engineering courses are built. Students are also exposed to cross-disciplinary engineering classes such as electromechanical energy conversion, Laplace transforms, control systems design, instrumentation, programming and electrochemistry.

By design, the program does not specialize in any one particular energy field. Students are exposed to a wide variety of energy systems, thereby maximizing their future employment prospects and career mobility. The program does emphasize so-called 'green building' through several classes (HVAC, energy systems management & auditing, energy efficient building design), as well as a photovoltaics-related set of courses (solid-state devices, photovoltaic systems design, power electronics and electric power conversion systems). But a liberal selection of elective courses and a broad general-engineering background serve to give students an expansive energy engineering background.

General Education Requirements for the BSREE degree include eighteen hours of communications courses, nine hours of elective humanities courses, six hours of elective social science courses and two required social science courses, HIST 356, History of Energy, and ECO 201 or 202, Principles of Economics, Macro or Micro.

Program Objectives and Outcomes

The program objectives were designed such that our graduates will have the fundamental engineering background required for successful careers throughout the energy industry cluster, particularly the industries pertaining to renewable energy. OIT's Electrical Engineering and Renewable Energy (EERE) Department has established the following objectives for its BSREE program:

- Graduates will excel as professionals in the various fields of energy engineering.
- Graduates will be known for their commitment to lifelong learning, social responsibility, and professional and ethical responsibilities in implementing sustainable engineering solutions.
- Graduates will excel in critical thinking, problem solving and effective communication.

Program outcomes are based on the ABET EAC outcomes, the so-called "a through k" outcomes, plus three additional program-specific outcomes, 'l', 'm', and 'n.'

(l) an ability to apply the fundamentals of energy conversion and application
(m) an understanding of the obligations for implementing sustainable engineering solutions
(n) an appreciation for the influence of energy in the history of modern societies

Table 1 - 2009-2010 BSREE Curriculum Map

Freshman Year Term, Fall Term		**Hours**
CHE 201	General Chemistry	3
CHE 204	General Chemistry Lab	1
MATH 251	Differential Calculus	4
SPE 111	Fundamentals of Speech	3
WRI 121	English Composition	3
Freshman Year Term, Winter Term		
CHE 202	General Chemistry	3
CHE 205	General Chemistry Lab	1
ENGR 266	Programming for Eng.	3
MATH 252	Integral Calculus	4
WRI 122	English Composition	3
Freshman Year Term, Spring Term		
REE 201	Intro. Renewable Energy	3
CHE 260	Electrochemistry	4
MATH 254N	Vector Calculus	4
WRI 227	Techn. Report Writing	3
	Social Science elective	3

Sophomore Year Term, Fall Term		
EE 221	Circuits I	4
PHY 221	General Physics w/ Calc.	4
MATH 321	Differential Equations	3
	Social Science elective	3
Sophomore Year Term, Winter Term		
EE 223	Circuits II	4
ENGR 211	Statics	4
PHY 222	General Physics w/ Calc.	4
ECO 20x	Principles of Econ	3
Sophomore Year Term, Spring Term		
EE 225	Circuits III - Laplace	4
REE 243	Electrical Power	4
REE 253	Electromech. En. Conv.	3
PHY 223	General Physics w Calc.	4

Junior Year Term, Fall Term		
EE 321	Electronics I	5
MECH 318	Fluid Mechanics	4
REE 331	Fuel-Cells	3
	RE Engineering Elective	3
Junior Year Term, Winter Term		
ENGR 355	Thermodynamics	3
WRI 327	Adv. Technical Writing	3
MATH 361	Statistical Methods	4
	RE Engineering Elective	3
	Humanities elective	3
Junior Year Term, Spring Term		
EE 419	Power Electronics	4
MECH 323	Heat Transfer	3
	RE Engineering Elective	3
	Humanities Elective	3
	Math/Science Elective	3

Senior Year Term, Fall Term		
EE 343	Solid-State Devices	3
MECH 433	HVAC	3
REE 339	Senior Project I	2
REE 463	Energy Sys. Instr.& Cont.	3
	RE Engineering Elective	3
Senior Year Term, Winter Term		
EE 456	Control System Design	3
REE 412	Photovoltaic Systems	3
REE 449	Senior Project II	2
SPE 321	Small Group/Team Com.	3
	RE Engineering Elective	3
	Social Science elective	3
Senior Year Term, Spring Term		
REE 413	Electric Power Conv. Sys.	3
REE 439	Energy Sys. Man. & Aud.	3
REE 455	En.-Effic. Building Des.	3
REE 459	Senior Project III	2
	Humanities elective	3

Five courses from the following

REE 344 Nuclear Energy
REE 345 Wind Power
REE 346 Biofuels and Biomass
REE 347 Hydroelectric Power
REE 348 Solar Thermal Energy Systems
REE 451 Geothermal Energy and Ground-Source Heat Pumps
REE 465 Renewable Energy Transportation Systems
Any upper-division EE, MECH or CE course, pending advisor approval

Program Assessment

Because the BSREE program is less than a year old, we have not yet sought ABET EAC accreditation. However, assessment of program objectives and outcomes has already begun with the goal of seeking ABET EAC accreditation under the General Engineering heading once a sufficient number of graduates has completed the program.

To ensure that the BREE program remains current and continues to serve all of the program constituents requires a comprehensive but efficient assessment effort. The following discusses how the BSREE program faculty collects, analyzes and then evaluates assessment data for program educational objectives and program outcomes. This plan is in accordance with ABET EAC Criteria 2, 3 and 8 as defined in the document "2007-2008 Criteria for Accrediting Engineering Programs."

For our process of outcomes assessment, we are using multi-outcome rubrics to assess engineering assignments that were designed specifically to measure program-level outcomes in addition to course-level outcomes. Because many of the "a through k" ABET outcomes are difficult to measure using traditional engineering assignments like problem sets, quizzes and exams, the programs within the EERE Department have developed so-called "ABET assignments." These ABET assignments are typically professional-style term papers (using ASHRAE or IEEE formats), laboratory reports (oral and written), project bids or proposals (using real clients and advise from employers), and class project reports. These assignments provide a broad and rich educational experience and ample opportunity for assessment. In addition to allowing faculty to efficiently measure multiple outcomes at once, the multi-outcome rubrics mapped to these assignments also provide direct feedback to our students, spurring them to improve their efforts to meet the program outcomes.

Program objectives, distinct from outcomes, provide broad statements that describe career and professional accomplishments that the program is preparing graduates to achieve, typically three to five years after graduation. The BSREE objectives were stated previously. Program objectives will be measured through several means. Uniquely at OIT, the BSREE program hosts its own Industrial Advisory committee (IAC). Through consultation with the IAC, we are developing a set of three surveys that will aid in our assessment of the program objectives. The surveys target renewable energy companies in general, employers of BSREE graduates specifically, and the graduates themselves. Once developed, these three surveys will be administered every three years. A focus group of IAC members and REE faculty will review the data collected and evaluate the results to determine if any corrective action may be needed.

The EERE Department receives an archival record from OIT Career Services (Survey of Graduates and Employers) on a yearly basis. This record provides data for assessment on employment placement rates and continuing education. It also provides contact information for BSREE graduates. We also maintain a list of companies likely to hire BSREE graduates, and a list of companies that have hired graduates and interns.

Ultimately, the BSREE objectives are mapped to the institutional objectives of OIT. This was done when we designed the program objectives; the institutional objectives were paramount as

we crafted the program objectives, thereby ensuring that the BSREE program serves the mission of the Oregon Institute of Technology.

Program Status

The BSRES program, established in 2005, started with 4 students. By 2007, 55 students had joined the program, many moving to Oregon from other states specifically to earn the BSRES degree. In the Fall of 2008, the BSREE program started, replacing the BSRES program. Student headcount in the Fall was 83, and Spring 2009 enrollment headcount is projected to be around 90. Notably, round 35% of these students are returning for a second bachelors degrees, most of whom are returning to school after earning a bachelors of arts.

During the twelve months of the 2007-2008 academic year (OIT Portland runs four terms, year-round), 210 prospective students contacted OIT requesting information about the BSRES degree, and 35 of these students matriculated in the Fall of 2008. In the six months since the beginning of the of the 2008-2009 academic year, 397 students have contacted the university requesting information about the BSREE program. It is not possible to determine if the change from BSRES to BSREE has played a roll in this increase, but it can be concluded that this renewable energy engineering program is generating a high level of interest from prospective students. The BSREE program has the ability to attract a large number of students to engineering, particularly students who have not previously considered engineering as a career pathway.

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