AC 2012-4802: DEVELOPMENT OF A MULTI-UNIVERSITY GRADUATE BIOENERGY PROGRAM

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Title:

Development of a Multi-University Bioenergy Graduate Program

Introduction

Widespread interest in green and sustainable industries is resulting from a general recognition of the need for systems that meet societal needs without long-term degradation of the environment. With the growing interest in bioenergy and sustainable technologies, there is a need for individuals with the knowledge and skills necessary to develop and sustain biobased enterprises. A new generation of professionals needs to be equipped to function in the interdisciplinary environment typical of biotechnologies and economies.

In 2006, a survey was conducted focusing on education for biobased materials processing that collected the perspectives of industrial practitioners who are aware of the experiential and educational needs of their current and future employees. The overwhelming message from the survey was that the employee pool lacked knowledge and experience with biobased processes. The survey findings demonstrated that there exists an urgent need for specialized training that is accessible for on-campus students as well as industry personnel who would like to pursue distance education while working full-time.

Four Universities are working together to develop a new graduate program that prepares participants for careers in the emerging biobased industries by enhancing their knowledge in renewable resource development. In order to optimize resources and to utilize expertise at multiple institutions, the program will be delivered via distance education through each of the partner institutions, making it accessible anywhere in the world. The multidisciplinary graduate program involves several different areas of study that will directly support biobased product and energy development, including chemical engineering, biological and agricultural engineering, plant sciences, and agricultural economics.

Project Objectives

- Develop a Bioenergy Graduate Certificate Program available online through each partner institution.
- Develop 6-8 new online courses on a range of topics related to bioenergy and sustainability, made available through each partner university.
- Build a multidisciplinary, multi-university faculty team to work together to continuously improve courses and programs related to bioenergy and sustainability.
- Develop comprehensive marketing efforts for the new program to yield maximum course enrollments.
- Train a greater number of individuals in the bioenergy and sustainability area to make positive contributions to this growing industry.

Framework for Program Delivery

The program is being delivered through the Agricultural Interactive Distance Education Alliance, AG*IDEA, which is an academic board within the Great Plains Interactive Distance Education Alliance. Great Plains IDEA is a national consortium of land grant universities collaboratively offering programs by distance education. Participating institutions have agreed to use a common

administrative platform, which allows students to enroll at their home institution, take online courses from any of the institutions participating in the program, and receive academic credentials from their home institution. Courses are cross-listed at each of the participating institutions, and all of the institutions agree to charge students the same price per credit hour. The tuition generated is apportioned between the teaching institution, the enrolling institution, and a portion is used for operating costs of the Great Plains IDEA consortium.

Program Development

The program was developed through funding from a USDA Higher Education Challenge Grant. Faculty involved on the planning team included 35 faculty members representing each of the four participating institutions and numerous disciplines, including Agricultural and Biosystems Engineering, Chemical Engineering, Plant and Soil Sciences, Agricultural Economics, Grain Science, Microbiology, Education, and Agricultural Communications. In addition to monthly conference calls, four face-to-face meetings of all faculty involved in program development have been held. Each of the four partner schools held a meeting on their campus, which included faculty professional development and tours of bioenergy program facilities and initiatives. The first and second meetings focused on curriculum planning and course development and the third and fourth meetings focused on program implementation. One additional face-to-face meeting is planned before the expiration of the grant.

In addition to curriculum and program development, the planning group also had to develop a business plan, which has been accepted by the AG*IDEA Board of Directors.

Graduate Certificate Program Curriculum

A new graduate certificate program was developed entitled 'Bioenergy and Sustainable Technology'. The certificate requires participants to complete a 15 credit hour series of courses, with 9 credit hours of required courses covering three core topics including biomass feedstock development, bioenergy economics and sustainability, and basic conversion technologies, which provide students with a broad background in renewable resource development. Several of the courses being offered were already in existence at one of the partner institutions, and eight of them were developed as new courses, with funding from USDA. Table 1 lists all the required and elective courses in the program. Following the table is a short description of each course available in the program.

Table 2 shows a schedule of the course offerings over a three year period. While the course schedule in the initial year of program implementation (2011-2012) is somewhat sporadic, the longer-term course sequence is well defined. The required overview courses are offered once every year, with Bioenergy Economics and Sustainability offered in the fall and Biomass Feedstock Development and Conversion Overview offered in the spring. Several other courses are also offered every year, but many of the specialized courses are only planned to be offered once every 2 years (Thermochemical Conversion, Crop Modeling, Feasibility and Commercialization, Bioseparations). Overall, there are a number of course options available each spring and fall for students interested in this area of study.

The target audience for the graduate program includes both generalists and specialists. Generalists may include administrators and managers with a desire to expand their general

knowledge in biobased processes. Specialists may include scientists and engineers as well as students in existing graduate programs that want to augment their education by taking one or more courses in the program. This certificate could be easily accessible by industry professionals, extension personnel, and potential students in remote locations.

Students entering the program may have baccalaureate degrees in agriculture, engineering, business, physical sciences, biological sciences, social sciences, or human sciences. Therefore, the curriculum must accommodate a wide range of educational backgrounds. The program is also designed to provide both breadth and depth. Participants work with their institutional advisors to develop a plan of study most beneficial to the student.

Table 1. Required and Elective Courses in the Bioenergy and Sustainable Technology Graduate Certificate Program.

Required Courses*	Elective Courses*
• Conversion Overview • Bioenergy Feedstock Production • Bioenergy Economics and Sustainability *all courses are 3 credit hours unless otherwise noted	• Thermochemical Conversion • Biochemical Engineering • Bioseparations • Fundamentals of Bioprocessing • Soil and Water Quality • Crop Modeling • Life Cycle Analysis • Bioenergy & Resource Economics • Community and Natural Resources • Risk Assessment • Feasibility and Commercialization • Sustainability Seminar (1 credit hour)

Course Descriptions

Conversion Overview (3 cr.) Overview of the technology involved in the conversion of biomass to energy, including associated sustainability issues. Overview of biomass structure and chemical composition; biochemical and thermochemical conversion platforms; issues, such as energy crop production related to water consumption and soil conservation. Further topics include: biomass chemistry, logistics and resources; biological processes; and thermochemical processes. *Prerequisite: College Algebra and a college science course.*

Bioenergy Feedstock Production (3 cr.) Overview of production and characteristics of cultivated crops, perennial grasses, and woody species as feedstocks for bioenergy. Fundamentals of plant growth factors, culture, harvest and storage, quality and improvement, and introduction to environmental impact, modeling, and resource utilization. Prerequisite: None. Knowledge of Microsoft-compatible word processing and spreadsheet programs including graphing is required. *Prerequisite: College Algebra; either College Biology or Plant Science; Preferred: Basic Chemistry or Soil Science.*

Bioenergy Economics and Sustainability (3 cr.) This course will provide an understanding of the economic issues relating to overall supply chains producing bio-energy and bio-based products. The course will address the economic, sustainability and social dimensions of these industries. Participants will gain an understanding of triple bottom line objectives, life cycle analysis and the principles of feasibility analysis. *Prerequisites: Introduction to Agricultural Economics.*

Thermochemical Conversion (3 cr.) This course will describe thermochemical methods to convert biomass to fuels and chemicals. Four general classes of conversion technologies will de described: liquefaction, pyrolysis, gasification, and heterogeneous catalysis. A general overview of these methods will be provided, but the main thrust of the course is to analyze the chemical reactions and chemical reactors associated with these methods. Extensive attention will be paid to reaction kinetics and to analyzing mass, heat, and momentum transfer in chemical reactors. These very general concepts will be applied to the specific cases of biomass gasifcation, liquefaction, pyrolysis, and catalytic treatment. *Prerequisites: Thermodynamics or a course in chemical reaction engineering or bioprocessing.*

Biochemical Engineering (3 cr.) The analysis and design of biochemical processing systems with emphasis on fermentation kinetics, continuous fermentations, aeration, agitation, scale up, sterilization, and control. *Prerequisites: Transport Phenomena.*

Bioseparations (3 cr.) Study of separations important in food and biochemical engineering such as leaching, extraction, expression, absorption, ion exchange, filtration, centrifugation, membrane separation, and chromatographic separations. *Prerequisites: Transport Phenomena II.*

Fundamentals of Bioprocessing (3 cr.) This course is designed for students who want a clear understanding of Bioprocessing principles as applied to the emerging bio-based industry. This course covers the fundamentals of mass and energy balances, fluid dynamics, heat and mass transfer, as applied to Bioprocessing. The microbial growth, kinetics and fermenter operation as applicable to Bioprocessing will be covered in this course. Industrial Bioprocessing case studies that involve the integration of the course contents will be discussed. *Prerequisites: Calculus or Analytic Geometry; Introductory Organic & Biochemistry; General or descriptive physics.*

Soil and Water Quality (3 cr.) An examination of the fundamentals of soil and water applied to proposed and existing bioenergy feedstock production systems. Current research results related to biomass removal and by-product addition to soils will be discussed and evaluated. *Prerequisites: Bioenergy Feedstock Production course or instructor permission.*

Crop Modeling (3 cr.) Systems approach is vital for overcoming challenges associated with food, fuel, feed and fiber production. The course uses crop simulation models & decision support systems to teach the systems approach concept to graduate students. Students will understand the basics of crop simulation models and will learn to use crop simulation models (CSM) as research, management, and policy tools. Students will use CSM as surrogates to field studies and learn to design experiments to fill in knowledge gaps. *Prerequisites: College Algebra; Introduction to Plant Physiology or Plant Science or the Bioenergy Feedstock Production course.*

Life Cycle Analysis (3 cr.) This course will examine the process and methodologies associated with Life Cycle Analysis. The participants will apply the methods developed in the course to a project to gain experience in defining and quantifying uncertainty associated with human perturbation, management and utilization of biofuels and other complex processes.

Bioenergy & Resource Economics (3 cr.) Bioenergy and Resource Economics surveys the allocation and conservation of natural resources from a perspective of optimal use and sustainability. Emphasis is placed on the tradeoffs and issues related to the production of biomass and development of the biofuels market including resource allocation, valuation methodology, economic growth, and market development. *Prerequisites: Calculus and Introductory Microeconomics.*

Community and Natural Resources (3 cr.) The course will introduce students to the breadth of consideration involved in community resource management. Included in the course are theoretical frameworks, methodological investigation and applied practices to enhance the ability of community development professionals to work with their communities to plan, develop, and monitor the conversation and development of natural resources with multiple functions.

Risk Assessment (3 cr.) This course will examine the process and methodologies associated with ecological risk assessments. The participants will apply the methods developed in the course to a project to gain experience in defining and quantifying uncertainty associated with human perturbation, management and utilization of biofuels and other complex processes. *Prerequisites: Calculus II and General Microbiology; Preferred – Familiarity with probability and statistics.*

Feasibility and Commercialization (3 cr.) Introduction to the concepts involved in feasibility and commercialization of biofuel and biobased products. Participants will gain an understanding of issues and processes in moving a project from pilot scale into commercialization.

Sustainability Seminar (1 cr.) Topics in environmental sustainability, green engineering, life cycle analysis, sustainable development, and sustainability science. *Prerequisites: Freshman-level College Chemistry or permission of the instructor.*

Table 2. Schedule of course offerings for the Bioenergy and Sustainable Technology Graduate Certificate Program. Each course is offered at one of the four participating institutions.

Year	Fall	Spring	Summer
2011-2012	• Thermochemical Conversion • Bioenergy Feedstock Production • Bioenergy Economics and Sustainability • Risk Assessment • Feasibility and Commercialization • Sustainability Seminar	• Conversion Overview • Bioseparations • Fundamentals of Bioprocessing • Soil and Water Quality • Life Cycle Analysis • Community and Natural Resource • Risk Assessment • Sustainability Seminar	• Sustainability Seminar
2012-2013	• Crop Modeling • Bioenergy Economics and Sustainability • Bioenergy and Resource Economics • Risk Assessment • Sustainability Seminar	• Conversion Overview • Biochemical Engineering • Fundamentals of Bioprocessing • Bioenergy Feedstock Production • Life Cycle Analysis • Risk Assessment • Sustainability Seminar	• Sustainability Seminar
2013-2014	• Thermochemical Conversion • Soil and Water Quality • Bioenergy Economics and Sustainability • Risk Assessment • Feasibility and Commercialization • Sustainability Seminar	• Conversion Overview • Bioseparations • Bioenergy Feedstock Production • Fundamentals of Bioprocessing • Life Cycle Analysis • Community and Natural Resource • Risk Assessment • Sustainability Seminar	• Sustainability Seminar

Program Review and Assessment

The mission of the Bioenergy and Sustainable Technology Graduate Certificate Program is to provide training for post-baccalaureate students in the development of renewable resources technology. The primary student learning outcomes for the program are:

1. Ability to articulate the multiple aspects of a biobased economy, including economic, environmental and social implications.
2. Ability to combine diverse concepts from multiple disciplines to effectively communicate, interact, collaborate and work in the renewable resources field.
3. Ability to utilize a systems approach to problem solving in this field.
4. Ability to apply the knowledge base of a specific discipline to this field.

Four different assessment tools will be used to evaluate student achievement of the learning outcomes, including individual course assessment, term project assessments, student exit interviews, and alumni surveys. A matrix showing the occurrence of student learning outcomes in each of the program courses has been created. Each course instructor is developing an assessment rubric for use in his/her course. Of particular interest are the three core courses (Bioenergy Feedstock Production, Conversion Overview, Bioenergy Economics and Sustainability) because nearly all students in the program will take all three of those courses. Specific assessment questions will be incorporated into all three core courses to assess student understanding of basic concepts and achievement of the learning outcomes. Term projects will be conducted in several courses, which will provide additional assessment opportunities.

Exit interviews and surveys will also be used as an important assessment tool. As students are completing the program they will be asked to complete a written survey as well as participate in an exit interview with the program director. This will assess student views of the program's contributions to their cross-disciplinary knowledge and their ability to communicate science, engineering, and economic aspects of a biobased economy. This will indirectly assess all 4 learning outcomes.

The final assessment tool will be an alumni survey. Questions regarding usefulness of the skills obtained in the program to achieving long-term employment goals will be incorporated into an alumni survey of students who have been awarded the certificate. Surveys will be conducted for two different timeframes, including one <5 years after completion and one >5 years after completion.

Assessment reports will need to be completed annually at each participating institution, and then results will be compiled for evaluation by the entire oversight committee, which includes representatives from all four participating institutions. The program is currently in its inaugural year, so assessment data is not yet available.

Unforeseen Hurdles

The multidisciplinary nature of the program necessitates that courses being offered come from a variety of different disciplines on each campus. The planning group is diverse, by design, and represents several different disciplines, but despite this diversity, in more than one instance, approval of a new course had to be sought through a department not represented in the planning group. This issue initially presented some hurdles related to program and course approval on each campus, but was overcome.

Program tuition costs have proven to be a hurdle in some circumstances. The first issue is that all institutions agree to charge students the same price per credit hour. At some institutions, this price is lower than their standard tuition rate, but at other institutions this price is higher than the standard tuition. For students choosing to take courses outside of their normal academic programs, paying a higher tuition rate may be a deterrent. The second issue is that in many graduate programs, students who are paid an assistantship receive some level of tuition waiver as a benefit, and may not normally have to pay for graduate courses. However, on most campuses the tuition waiver does not apply to courses taken on-line from other institutions, thus deterring enrollment in these courses by traditional graduate students. Potential solutions will likely have to evolve at individual institutions.

The most important area of future work involves marketing the program. Targeting non-traditional students will be critical to the future success of the program, especially since in many cases there is an added cost for traditional graduate students to enroll in these courses. Planned marketing efforts include use of professional listservs, presentations at professional conferences, and social networking.

Project Outcomes

A new graduate certificate program in 'Bioenergy and Sustainable Technology' has been developed on four different campuses and is being offered via the AG*IDEA consortium. This collaborative, multi-university approach will impact education in renewable resource technologies in several ways. Students will be taught by faculty from multiple universities in multiple disciplines, providing them a powerful educational experience and the ability to network with diverse experts in the field. Through course sharing and co-teaching of courses, participating institutions are able to offer higher quality curricula, covering topics which may not be available at each institution. University human and financial resources are also optimized. This program provides an efficient solution to expanding educational demand in emerging areas. In addition, it provides post-baccalaureate students with an educational opportunity that bridges multiple disciplines, is accessible anywhere in the world, and will likely lead to new technological advances in the processing of renewable resources.