

**Recommendations for Implementation of Energy Initiatives
September 17, 2009**

EXECUTIVE SUMMARY:

We identified two top priorities for immediate implementation and one longer-term priority, all of which are consistent with the College's strategic initiatives on energy. Currently, dozens of scientists at Penn State conduct research on biomass energy in isolation of each other, without appropriate facilities or integration of disciplines to work at the cutting edge of bioenergy and bio-based R&D. To take our expertise to the next level and to meet the immediate and future demands for bioenergy and biomass value-added products, shared research facilities are required that are at a commercially relevant scale to facilitate realistic, comprehensive multi-disciplinary research, teaching, and extension from "fields to wheels." In planning such a venture, the University must take into consideration the current landscape of bioindustry development and look to the cutting edge of bio-based R&D. Also, energy efficiency is critical for the development of sustainable agriculture and communities, and is a prerequisite for alternative energy strategies. It will likely continue to grow in importance in the foreseeable future, yet we lack a coordinated effort to address it in our College and engage our students to embrace it as part of their lifestyle. Finally, there is a critical need to develop a Center for Policy Analysis. This is a longer term, integrated concern for the College. This center would coordinate and synergize a broad set of applied policy-related analysis targeting important energy, environmental and land use topics. Such a center would address emerging needs and issues related to the current strategic areas for the College.

The Energy Initiative Team recommends the following initiatives for strategic implementation:

INITIATIVE 1. Integrated Bioenergy and Bio-based Materials Research Facilities

Action items:

- **Initiate common, long-term field sites for biomass production research**
- **One new faculty hire to nucleate a bio-based materials program**
- **Staffing and improvement of biofermentation and bioconversion facilities**
- **Develop a new professional masters program and CE courses to support Education, Outreach and Extension programs**

INITIATIVE 2. Energy Efficiency and Use in Agriculture and Communities

Action items:

- **Hire a new faculty member in the area of energy efficiency who can grow this important topic and knit the existing efforts of the college into a cohesive program**
- **Bring faculty from around the college to participate in joint activities surrounding the theme of energy efficiency**
- **Initiate a seed grant program targeted at developing short term projects within various disciplines**
- **Incorporate energy efficiency more broadly in our Extension programming**

LONG-TERM INITIATIVE. Renewable and Conventional Energy Policy Issues: Center for Policy Analysis

Action items:

- **Over the next year, bring the interested parties across the university together to discuss the scope and structure of a policy center**
- **Hire a non-tenure track managing director to organize the center for policy analyses.**

INITIATIVE 1. Integrated Bioenergy and Bio-based Materials Research Facilities

At Penn State, dozens of research groups conduct projects on specific aspects of biomass energy. In fact, Penn State has a strong R&D portfolio in practically every area in the biomass to fuels, bio-based materials, and energy supply chains, encompassing the full range of basic and applied biomass energy research topics. However, individual faculty member's research projects are typically conducted in isolation, without the opportunity to place the research results within an holistic context of energy and value added materials production, making it difficult to know how improvements in one area can affect the system overall. The lack of cross-fertilization between different R&D programs within the University is especially disadvantageous in an emerging bioindustry that is comprised of many crosscutting disciplines. Furthermore, acquiring the support, space, and facilities required to get an individual biomass project off the ground can be daunting, and may be needlessly and inefficiently repeated many times over among projects.

It has become clear that successful biomass programs are expected to both cover and integrate research and training activities across the entire value chain, to attract major funding and to achieve significant accomplishments in the area. Our research activities should be integrated in a manner consistent with sustainable bioenergy approaches, from sustainable biomass cropping systems, to alternative biofuels, bioenergy and bio-based materials production methods, to developing supply chain and infrastructure strategies, as well as environmental and economic risk assessment, with planning and economic analysis at the landscape level.

To take our interests and expertise in bio-based R&D to this level, shared research facilities are required that are at a commercially relevant scale to facilitate realistic, comprehensive multi-disciplinary research, teaching, and extension from "fields to wheels." In planning such a venture, the University must take into consideration the current landscape of bioindustry development and look to the cutting edge of bio-based R&D. In particular, the College should take the following actions, which will form a solid basis for larger, university-wide efforts:

- **Initiate common, long-term field sites for biomass production research.** This will enable researchers from multiple disciplines to work within the same production systems, to study the effects of the same perturbations and to collect the same data sets for direct comparisons. Our ecologists will be able to study nutrient cycling and species diversity at the same sites where we are testing different agronomic approaches, while our hydrologists can also study run-off and water requirement issues and economists study inputs and outputs financially. These common, long-term field tests will become powerful demonstration sites for educating our students, public stakeholders, government and industry. If large enough in scale, the common research sites will be able to supply the quantities of biomass feedstocks that companies are actively seeking from us as the

first step in citing pilot plants and production facilities locally. These long term research sites will also continuously produce the uniform feedstocks which our engineering research groups require for research on methods of feedstock conversion to liquid fuels. The field site component of shared bioenergy research facilities can be accomplished by the College setting aside lands dedicated to this purpose at the Rock Springs and Stone Valley research farm and forest sites, and perhaps also the Biglerville and other University owned sites as well. The specific sites will need to be carefully chosen to be representative, and be fenced in for protection from deer. Staff will need to be committed to maintaining the research sites. The selection and preparation of sites can be accomplished during the next academic year, with the College's backing. College backing can include the commitment of competitive seed grant funds to this for one year. This is entirely consistent with the fact that the shared research sites will seed many projects and funding opportunities in the future. For the Pennsylvania ecosystem, there is an emphasis on perennial crops that can be intensively managed. Perennial biomass crops such as hardwood trees and grasses require years to establish, and thus should be an early target for the establishment of improved, shared long term field sites.

- **One new faculty hire to nucleate a bio-based materials program (see Appendix B for example).** To help create a sustainable bioindustry space, it will be critical for our R&D program to look past the conventional approach of making only fuels and CHP from biomass. Commodity biofuels cannot form the basis of an economically or environmentally sustainable industry whether starch (i.e. corn) based or cellulose based. There is an opportunity to enhance bioindustry R&D through intra- and inter-College collaborations, but the window of opportunity won't be open long. Like the petroleum and paper industries, economic return will likely come from value-added bio-derived chemicals and bio-based materials. Penn State is a national leader in materials science and engineering, and with the construction of the Millennium Science Complex hopes to capitalize on the intersection of the life and materials sciences. The College of Agricultural Sciences should position itself to be an active participant in this endeavor. A critical step will be to partner with EMS capabilities in catalytic chemistry to produce a varied slate of high value bioproducts that can enable bioindustry development. The work presently being conducted on this topic within the College of Agricultural Sciences and at Penn State more broadly, while significant, is piecemeal and unorganized. At least one faculty hire would be required to effectively nucleate a bio-based materials program. Proposed is a faculty position in what the National Academy of Sciences calls *biomolecular materials and processes*. Depending on the overall focus of the program, hires could be made in a number of subspecialties including: bioplastics, specialty chemicals from biomass feedstocks, biopolymers, polymeric or fiber-based packaging, or adhesives. Bio-based materials scientists would find collaborations with the Department of Materials Science and Engineering (EMS), the Center for the Study of Polymer Systems, the Biomass Energy Center (CoAS) and the Wood Products (sustainable building materials) program, especially the Center for Nano-cellulosics. A few fledgling efforts in this area exist nationally, but by coupling current expertise to several new positions, Penn State could quickly take on a leadership role.

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- **Staffing and improvement of biofermentation and bioconversion facilities.** The goal of upstream biomass production research projects is to improve downstream production in an environmentally-sustainable manner. That ultimate target requires validation, and we have the resident expertise to provide that information in our biomass projects. However the current facilities for conducting biofuel conversion tests and for thermal energy production are limited. In order to have a robust research facility, thermal conversion techniques such as gasification, torrefaction and pyrolysis need to be implemented alongside biofermentation facilities and value-added products R&D. The integrated biofermentation/bioconversion test facilities should be upgraded to accommodate larger pilot-scale tests of wood chips and a variety of lignocellulosic biomass feedstocks. These shared field test sites and lab facilities will provide the core of many student research theses and collaborative projects within the College and across the University. Improving our biofermentation/ bioconversion test facilities will require larger up front financial support. The first step in accomplishing this could be the preparation of an equipment grant proposal over the next year for submission to NSF and/or DOE. The College can encourage and support the preparation of the grant proposal by stating its commitment up front to champion the proposal through the university down-selection process.
- **Education, Outreach/Extension and professional development programs.** The new hire(s) would collaborate with existing faculty in the development of Biorenewable Resources programs integrated with Outreach and Extension programs by the CoAS. These programs could potentially offset the cost of facility improvement and provide addition funds for energy research to units which participate.

We propose a suite of education and professional development courses around bioenergy and bio-based products:

- **Professional Science Master's in Bioenergy and Biobased Products** - For a sustainable Biorenewable Resources industry to develop in the US, a professional work force must be trained in the appropriate scientific disciplines grounded in the objectives and practical needs of such an industry. A large and unmet demand exists for training of professionals at the Master's level with skills in applied science, communication, business, and industry perspectives for this emerging sector. Penn State is well positioned to provide a graduate program to serve this market. Faculty from the College of Agricultural Sciences, the College of Earth and Mineral Sciences, the College of Business, and the College of Engineering have recently started to plan such a program together. We propose a new Professional Science Master's Program in Biorenewable Resources with an initial option focused on Bioenergy and Biobased Products, with later expansion to related options in Renewable Technologies (solar, wind, geo, etc.) and Sustainable Building Technologies. The program will be offered as a series of continuing education courses, intensive hands-on workshops and internships through Penn State's World Campus program. The core courses for the program and the Bioenergy and Biobased Products option will include Renewable Energy, Sustainability, Energy Economics, Biomass Feedstocks, Production Technologies, and Human Dimensions of BioEnergy (Appendix D). The adoption of

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courses to an on-line format and the preparation of the Graduate School proposal will require a significant investment of time and effort for which we request support from the College and units.

- Certificate courses – Selections of courses can be designed to provide training in specific areas such as fuel handling, focusing on ASTM, OSHA and other regulatory training. This training would be appropriate for trade organizations to prepare them for changes in equipment, specifications and handling of bio-based products as they enter the market.
- Non certificate courses – Individual survey level courses can be provided to give a broad background around the social, economic and ecological benefits associated with engaging local communities in bioindustry development.
- Associates Degree programs at Commonwealth campuses – Campuses like Greater Allegheny and Dubois have already begun to investigate biomass/energy related pathways. There is an opportunity for different campuses, either individually or by teaming, to offer different bioenergy associate degree programs in biofuels, ag, forestry, wind, solar, hydro, policy, etc...
- Undergraduate major and minor bioindustry programs (See Appendix A for details)
- K-12 Curriculum - Develop an age/grade appropriate education program where students are taught the basic ideas related to carbon footprints and practicing sustainable habits. This would include trips to farms, bioenergy plants, films at museums, talks and demonstrations by PSU Extension officers at their schools, etc.
- Support the current community and agricultural information programs.

Metrics: The success of the action plan to implement this initiative can be monitored in future years by several indicators such as the number of multitrophic, multi-disciplinary research projects that are started and ultimately externally funded, courses and student theses that integrate their studies using this facility, and applied examples at the field sites and the bioconversion facilities. We will also monitor the use of the field sites and lab facilities for their use in extension, continuing education and outreach exercises.

INITIATIVE 2. Energy Efficiency and Use in Agriculture and Communities

Energy efficiency is critical for the development of sustainable agriculture and communities and is a prerequisite for alternative energy strategies. It will likely continue to grow in importance in the foreseeable future, yet we lack a coordinated effort to address it in our College and engage our students to embrace it as part of their lifestyle.

Energy efficiency is covered in the Energy Management Systems course taught by Dennis Buffington in Ag and Biological Engineering and likely addressed to some extent in other

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courses throughout the College. Energy efficiency is also a key part of one or more courses in greenhouse management in Horticulture. Much of the College's Extension efforts are focused on our website <http://energy.cas.psu.edu> and through a range of activities conducted by Buffington and the newly formed extension Energy Efficiency program team, which is planning workshops related to dairy, poultry and greenhouse facilities. Energy efficiency research is also a key part of Buffington's program and has resulted in the development of the popular Energy Selector. He has also been involved in energy efficiency research with the mushroom industry and other issues. The Department of Ag Economics and Rural Sociology conducts energy efficiency policy research on several levels. There are some research programs in the College such as the Green Roof Center, which ultimately leads to improved energy efficiency in buildings. Several extension programs incorporate aspects of energy efficiency, such as the animal housing program (Eileen Wheeler), and the waste to energy program (James Garthe). The Extension efforts of Dennis Buffington are currently focused on energy efficiency and utilization. In addition, several faculty and educators are providing a leadership role in the Energy Efficiency Program Team for the Renewable and Alternative Energy Natural Work Group.

We work with numerous partners on campus on energy efficiency topics, which include the Office of Physical Plant, the Center for Sustainability, PennTap, Outreach and PSIEE coordinated through the Environment and Energy Outreach team. However, our collaborations need to multiply, which would increase our visibility in the University community and enhance potential for joint project development. Many external organizations have approached the College in some fashion on energy efficiency initiatives, including the PA Department of Environmental Protection, numerous local communities, farm organizations, and federal agencies, such as USDA-NRCS. Due to staffing constraints, we have had limited ability to respond to these opportunities. We recommend the following actions to implement this initiative:

- **Hire a new faculty member in the area of energy efficiency who can grow this important topic and knit the existing efforts of the college into a cohesive program.** There is a distinct lack of a focal point for coordination and full development of this important area – especially in the case of teaching and research. The lack of research in this area is a distinct shortfall within the college, and it would be excellent to develop a program in this area, perhaps focusing on full-system energy efficiency analysis and optimization for bioproducts or aimed at developing a “zero net energy farm” concept in Pennsylvania. Energy efficiency needs to be incorporated more broadly in our curricula across the College, especially providing students the quantitative skills to assess energy efficiency in their disciplines and providing opportunities for students to become engaged with the University community and faculty in our College. Projects or activities such as the Solar Decathlon in engineering are good examples of what could be developed in the College. Energy use and efficiency could be an important part of a renewable bioresource minor that might be developed as part of our overall strategy.
- **We propose a new initiative to bring faculty from around the college to participate in joint activities surrounding the theme of energy efficiency.** The initial effort could be a College-wide conference on energy efficiency in agriculture and communities. With a minimal investment, this would help to showcase college programs in this area, develop opportunities for education and research, and engage external stakeholders.

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- **Initiate a seed grant program targeted at developing short-term projects within various disciplines.** This would develop marketable stories to improve the College visibility in this area. Projects that use our facilities as test-beds for the development of innovative energy efficient tactics and collaborate with other entities on campus should be high priority projects. There are already some potential examples of energy efficiency tactics being implemented on the College farms and facilities that could be showcased now.
- **Incorporate energy efficiency more broadly in our Extension programming.** Energy efficiency and use Extension activities could be expanded to include field crops, animal production, and our food system. Future Extension activities could include educational programs that address some recent state initiatives to reduce energy consumption such as Act 129 and could focus on developing the expertise among our clientele to perform comprehensive energy audits in agricultural settings. We should capitalize on federal and state programs that incentivize energy efficiency projects and education. Development of youth programs in energy efficiency is critical as well and should be incorporated in future youth programming efforts.

Metrics: The number of new courses and students trained in energy efficiency topics can be tracked. Also the number of seed grants and competitive state or federal grants awarded to study energy efficiency in the College can be tracked. The number of Extension activities, publications, web site hits, and users served on this topic can also be tracked.

LONGER-TERM INITIATIVE. Renewable and Conventional Energy Policy Issues: A Center for Policy Analysis

This priority area represents a longer term and integrative concern for the College: Developing a center to coordinate and synergize a broad set of applied policy-related analysis targeting important energy, environmental and land use topics. Such a center would address emerging needs and issues related to the current strategic areas for the College. (Of the five areas of energy; water quality and quantity; pest prediction and response; food, diet and health; and entrepreneurship, the first four would be especially well served by this policy analysis center; the fifth may be addressed by a new Center for Entrepreneurship, and also falls within the purview of the Center for Economic and Community Development within the Dept. of AERS).

A policy analysis center would bring together and develop college expertise—particularly research and outreach—based in relevant techniques and approaches, such as choice modeling, social impact assessment, monitoring and evaluation studies, strategic environmental assessment; sector analyses, and other modes of public policy analysis to determine the impacts of different policy alternatives for addressing pressing societal concerns. With this toolbox of social science methodological resources identified and brought together within the College (which would in turn allow more formal coordination with units in other colleges with related or complementary expertise), the College will be in a stronger position to address issues of urgent importance to

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various college stakeholders. With regard to energy, this would include issues such as the multiple impacts of Marcellus Shale gas development, carbon management and policies, renewable energy standards, biorefinery location and investment, and youth and workforce training and development in renewable energy and conservation. The center would emphasize techniques and tools that can be used for analysis of a broader set of issues addressed by CoAS, not only energy. Although energy may be the issue *du jour*, the college currently addresses other issues that would benefit from such policy analyses. There may be new, as yet unknown issues emerging in the future, and a general set of analytical tools and capacities could be applied very productively to all such issues, not only energy.

Such a center would be either based in or affiliated with the Environment and Natural Resources Institute (ENRI). Many faculty members within the Department of Agricultural Economics and Rural Sociology are currently doing applied research on the broad energy, environmental and land use topics that would be immediately relevant to the center. With appropriate technical support (i.e., research and outreach specialists), such a center holds considerable potential to deliver research reports and analyses that will address specific questions and concerns of diverse stakeholders in Pennsylvania and beyond.

Some models for such a center exist at some of our peer institutions. One example is the Land Policy Institute at Michigan State University: http://www.landpolicy.msu.edu/modules.php?name=Pages&sp_id=1&pmenu_id=1. Another is the Center for Energy, Economic and Environmental Policy at Rutgers University: <http://policy.rutgers.edu/ceeep/>.

Because this is a longer-term initiative, we recommend the following actions to jump start the process of developing a center:

Action Items:

- 1. Over the next year, bring the interested parties across the university together to discuss the scope and structure of a policy center.**
- 2. Hire a non-tenure track managing director to organize the center for policy analyses.**

Appendix A: Undergraduate Major and Minor Bioindustry Program

Core Courses

- Calculus I and II
- Physics I and II
- Biology
- Microbiology
- General and organic chemistry

Chemical Engineering

- Principles of chemical engineering processes
- Thermodynamics (chemical engineering)
- Heat transfer
- Mass transfer
- Unit operations
- Process design and economics
- Process Control
- Process modeling/design project

Agricultural Engineering

- environmental influences on biological systems
- modeling of biological and physical systems
- transport phenomena in biosystems
- engineering elements of biochemistry and microbiology
- soil and water conservation engineering
- natural resource conservation and protection
- Agricultural Systems Analysis and Management
- Forest management

Supply Chain

- third-party logistics providers
- transport system enterprises

Microbiology

- Fermentation
- Aquatic Microbiology

Fuels

- Combustion/gasification and pyrolysis theory

Sustainability

- Social, economic, environmental and policy related issues to creating and sustaining a bioindustry in rural areas.

Appendix B: PSIEE Proposal for Faculty Position

INTEROFFICE CORRESPONDENCE

Date: February 23, 2009
From: Greg Ziegler
To: John Floros, Professor and Head of Food Science
Re: PSIEE Energy Solicitations 2009

PSIEE has issued a request for proposals for co-funded faculty positions with 1-paragraph letters of intent due by March 2 and 3-page final proposals due April 20, 2009. While the title “New positions in Energy Sciences and Engineering” and the hiring priorities would suggest that the PSIEE is really the PSIE (with little emphasis on Environment), the category *Bioenergy Science and Systems* does include production of “biomaterials” (which I believe should be bio-based materials), and opens a small crack for this proposal.

Attached to this memo is a proposal for a PSIEE co-funded faculty position in what the National Academy of Sciences calls *biomolecular materials and processes* for submission to Dean Steele (*Inspired by Biology: From Molecules to Machines*, National Research Council, 2008). With our expertise in biopolymers, the Department of Food Science has much to offer this endeavor. This position could complement the PSIEE co-funded synthetic biology engineer currently being recruited by ABE.

This proposal capitalizes on Penn State’s preeminence in materials science to establish a program in bio-based materials, and like the category *Materials for Energy*, builds collaborations between PSIEE and MRI. A few fledgling efforts in this area exist nationally, but coupling current expertise to a new position, Penn State could quickly take a leadership role. Below I have summarized/outlined the proposed position including some possible sub-specialties.

1. Bio-based materials scientist (biomolecular materials scientist)
 - a. Polymer (bioplastic) or feedstock synthesis from biomass
 - b. Biopolymers/Natural Polymers
 - c. Packaging (polymeric or fiber-based)
 - d. Adhesives (microbial or biopolymer-based)

The bio-based materials scientists would find collaborations with the Department of Materials Science and Engineering (EMS), the Center for the Study of Polymer Systems, the Biomass Energy Center (CoAS) and the Wood Products (sustainable building materials) program, especially the Center for Nano-cellulosics. Presently, Jeff Catchmark (ABE), Mike Orzolek (Hort.), Jim Runt (MatSE) and myself have secured a CoAS seed grant to explore a program in bioplastics for green plasticulture.

This effort could easily extend to green food packaging with the addition of a faculty position in biomolecular materials science.

Bio-based Materials Scientists

1. Abstract

This proposal capitalizes on Penn State's preeminence in biomass energy and materials science to establish a program in *bio-based materials*. A few fledgling efforts in this area exist nationally, but by coupling current expertise to several new positions, Penn State could quickly take on a leadership role. In addition to energy, the development of biomass-based feedstocks and bio-based materials will be critical to the long-term sustainability of a bio-based economy. While fuel is a commodity, bio-based materials have the potential to add a significant economic value to low cost inputs. The bioenergy industry produces valuable byproducts, such as glycerol from biodiesel, that can replace petroleum-based feedstocks, and ethanol with its relatively low energy yield may be better utilized as a feedstock for specialty chemicals manufacture. The economic viability of bioenergy refineries will hinge on the production of value-added streams.

I propose a faculty position in bio-based materials science at the assistant professor rank to be housed in the College of Agricultural Sciences (CAS), department of Food Science. Within the CAS, this person(s) would likely collaborate with colleagues in Agricultural and Biological Engineering and the School of Forest Resources (Wood Products). It would be expected that the individual(s) would be active in Penn State's Biomass Energy Center. External to CAS, numerous potential collaborations exist with faculty in Materials Science and Engineering, especially the polymers group. Joint appointments are a distinct possibility.

2. Nature of Appointment

Assistant Professor of Bio-based Materials Science in the College of Agricultural Sciences with strong possibility for joint appointment in the Department of Materials Science and Engineering in the College of Earth and Mineral Sciences. The anticipated salary is \$70,000-\$80,000, with start-up costs of approximately \$250,000. Potential starting date is Fall 2010. Among the possible sub-specialties such an individual(s) might have, *synthesis of polymers from biomass and natural polymer chemistry* are priorities.

3. Program Relevance

Food and beverage packaging accounts for about 70% of the more than \$100-billion packaging market in the U.S. and more than half the \$400-billion worldwide market (*Green Plastics*, E.S. Stevens, 2002). Food packaging is the largest source of landfill waste. As E.S. Stevens says, "There is something downright silly in wrapping a sandwich in a package that will last fifty years."

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In relatively recent news, Dow has announced plans to manufacture “cost-competitive,” biomass-based, linear low density polyethylene (LLDPE) from sugar via ethanol for films and food packaging., and Braskem plans to make HDPE from sugar beginning late 2009 (*C&EN*, July 23, 2007, p. 17). Huntsman Corp., Archer Daniels Midland and Cargill are taking advantage of the surplus in glycerol generated by biodiesel production to manufacture chemicals such as propylene glycol. Dow is planning to manufacture the raw material for epoxy resins, epichlorohydrin, from the same source (*C&EN*, May 7, 2007, p. 14). Specialty chemical firm Vertellus Specialties is collaborating with Cardiff University (UK) to expand the potential of glycerol as a feedstock.

DuPont and the starch company Tate & Lyle have formed a joint venture to manufacture and market 1,3-propanediol (Bio-PDO™) from corn sugar. Bio-PDO™ can be used in cosmetics, detergents, anti-freeze, and as a monomer for the production of unsaturated polyester resins and specialty polymers. The Bio-PDO™ process is said to consume 40% less energy and 20% less carbon dioxide than petroleum-based propanediol.

The production of biofuels and feedstocks in the form of 5-hydroxymethylfurfural (HMF) and 2,5-dimethylfuran from sugar (glucose and fructose) has recently been described (*Science* **2007**, 316, 1597; *Nature* **2007**, 447,982). This conversion was obtained using catalytic methods instead of fermentation. HMF derivatives can replace petroleum-based building blocks used to make plastics, pharmaceuticals and fine chemicals, but are rarely used due to their otherwise high cost (*C&EN*, June 25, 2007, p. 8).

The July 13, 2007 edition of the *Chronicle of Higher Education* carried a story on commercialization of a method for bonding insulating materials using mushroom mycelia. The process uses less energy than the manufacture of alternative building materials and without petroleum or chlorofluorocarbons. A newly formed specialty business unit of The Dow Chemical Company, Dow Wolff Cellulosics is expanding its capacity and capabilities. The new facility is expected to come on stream in the first quarter 2009 and will produce methylhydroxyethylcellulose primarily for the construction materials market. For the past several years, the cellulose industry has been experiencing a strong increase in worldwide demand across many end-use applications. Industry analysts estimate the worldwide market for methylcellulosics has grown by approximately 6% in 2006 and is expected to grow at least at a similar rate in 2007

Among the evidence for an academic interest in bio-based materials is the new (2007) *Journal of Bio-based Materials and Bioenergy*, and the publication of the book *Bio-based Polymers and Composites* by Richard Wool and Susan Sun (2005). The 2007 Annual Meeting of the American Chemical Society (ACS) includes a section titled, “Feedstocks of the Future II: The Organic Chemistry of Biomass.” The ACS presented the inventors of the Bio-PDO™ process mentioned earlier the 2007 Heroes of Chemistry award.

A position in bio-based materials science should be able to attract funding. USDA and DOE announced a joint solicitation for biomass research and development totaling \$18 million for FY'07. The program funds research and development of *biomass-based products*, biofuels, bioenergy and related processes (released June 11, 2007). President Bush's proposed Farm Bill includes \$1.6 billion in renewable energy funding including \$500 million over 10 years for bioenergy and *bio-based materials research*. Penn State has been very successful in competing for USDA-NRICGP funds from program 71.2, Non-food uses of agricultural materials, garnering three of those grants this year. Penn State (IRO) has been approached by a major chemical company to explore research on the synthesis of olefins from biomass. While several large joint ventures between energy companies and universities have been announced, biofuels appear to be the focus. This gives Penn State the opportunity to differentiate itself by emphasizing bio-based materials.

Such expertise would also give Penn State the opportunity to develop interdisciplinary educational programs in bio-based materials processing. According to Michael Pacheco of the National Renewable Energy Laboratory (Golden, CO), "integrated programs [in biofuels] recognize that this isn't a discipline-specific program...a traditional biochemistry or chemical engineering program won't really prepare you to work in biofuels" (*C&EN*, April 30, 2007, p. 40). The same could be said for bio-based materials.

4. Supporting Materials

We have discussed this proposal with Gary Messing, Distinguished professor and Head of Materials Science and Engineering, and Jim Runt, Director of the Center for the Study of Polymer Systems, and both thought there were real opportunities in bio-based materials. Should this proposal get beyond the CAS, we would work with MatSE to investigate the possibilities of co-funded positions.

College-specific issues:

1. College priority

a. Relevance to strategic plan

The position described in this proposal will help the COAS advance its goal of Achieving Excellence through an Interdisciplinary and Multifunctional Approach, and of being a catalyst in expending Penn State's opportunities in bio-based systems. The faculty member could contribute to a new interdisciplinary minor in biorenewable systems, and offer continuing education courses in production and use of bioplastics.

Under the CAS emphasis on the Food and Fiber System is the development of new markets for value-added products.

A significant opportunity for our college—the potential for developing and accepting biobased resources—exists at the interface of the food and fiber, ecosystem, and socioeconomic systems. Biobased resources are renewable and can be used to produce a variety of value-added materials in addition to their well-recognized importance as alternative energy sources. The agricultural industry has been identified as a key source of biobased resources. Our college can be a catalyst in expanding Penn State's educational and research opportunities in biobased systems. In our vision for biobased products, we can contribute in areas such as novel uses for wood and other plant-based materials; development of new products for human, animal, and plant health and nutrition; biobased fuels and lubricants; and a variety of biomimetic (materials designed to mimic biological characteristics) products and devices. A biobased economy also provides new opportunities for rural communities and will require science-based policy decisions, both of which we are well positioned to lead. We will endeavor to enhance linkages with the Materials Research Institute and campus-wide energy initiatives while taking a strong role in regional and national efforts within the land-grant community.

b. Expected Collaborations

As stated previously, significant collaborations outside the CAS with MatSE, Chemical Engineering and the Materials Research Institute are anticipated. Intracollege collaborations with Wood Products is expected, especially with the Center for Nano-cellulosic Materials and the Center for Plasticulture.

c. Scientific merit

The BioEnvironmental Polymer Society and the Biodegradable Products Institute are hosting a meeting this summer titled “Polymers and the Environment, Emerging Technologies and Science,” and the European Polysaccharide Network of Excellence is hosting a meeting this September in Finland titled, “Polysaccharides as a Source of Advanced Materials.”

The scientific merit is exemplified by the citations from *Science* and *Nature* in the body of the proposal text. Cornell's Center for Materials Research (CCMR) has a program in Green Composites & Chemistry with research programs on unique applications of natural fibers and polymer synthesis from agricultural byproducts (<http://www.ccmr.cornell.edu/industry/greenmaterials/>). A new multistate initiative SDC325 titled, “The Science and Technology for a Bio-based Industry and Economy” is being organized. Among its objectives are “develop, evaluate, and optimize integrated processes to convert biomass

resources into commercial applications for biochemicals and biomaterials.” The productivity of the programs of Richard Wool, Professor of Chemical Engineering and Director of the Affordable Composites from Renewable Resources Program at the University of Delaware, and Susan Sun, Professor of Grain Science and Industry and Director of the Bio-Materials & Technology Laboratory at Kansas State, are evidence of successful academic programs in the field of bio-based materials science.

2. **T/R/E split:** 25/75/0
3. **Essential elements of start-up package:** This would likely include the necessary laboratory equipment for chemical synthesis. The Department of Food Science already has considerable capacity for characterization of any derived bio-based materials. The likely startup costs would be approximately \$250,000.

Assistant Professor of Bio-based Materials Science and Engineering

Research responsibilities: Establish a strong externally-funded research program in bio-based (biomolecular) materials science and engineering. Appropriate research areas would include bio-based materials, green food packaging, bioplastics, or bio-derived materials.

Significant resources available to the successful candidate include access to extensive pilot plant facilities and high-end research instrumentation for materials characterization. The candidate will be expected to collaborate with colleagues in the Department of Food Science (www.foodscience.edu) and others across the University, especially Penn State’s Institute for Energy and the Environment.

Teaching responsibilities: Develop and teach a graduate-level course in the candidate’s field of specialization, and an undergraduate course on food packaging. Participate in a collaborative biorenewable systems minor. Supervise graduate students in thesis research and advise undergraduate students.

Qualifications: Applicants should have a Ph.D. in Food Engineering, Chemical Engineering, Materials Science and Engineering, or a relevant field of specialization. Postdoctoral experience is highly desirable. Applicant should possess a willingness to work as part of a multidisciplinary team.

Appendix C: Inventory of programs in the topic area at Penn State University

An inventory of undergraduate, graduate, and extension programs and key research programs underway in the topic area at Penn State University.

Compiled by Ketja Lingenfelter, Office for Undergraduate Education, April 2009

A web search for energy, renewable energy, biofuels and bioprocessing yielded the following results:

Undergraduate Majors:

- Biological Engineering, Joint offering in College of Agricultural Sciences and College of Engineering – courses support the processes to develop bioenergy, and extensive research is occurring in this area. Course titled Biomass Energy is taught by Dr. Tom Richard.
<http://www.abe.psu.edu/BEmajor.html>
- Energy, Business and Finance (EBF), Joint offering in College of Earth and Mineral Sciences and Smeal College of Business
<http://www.ems.psu.edu/students/EnergyBus.html>
- Energy Engineering (ENENG), College of Earth and Mineral Sciences
<http://www.eme.psu.edu/energyeng/>
- Civil Engineering, College of Engineering
<http://www.engr.psu.edu/ce/undergraduate.html>
- Chemical Engineering – emphasis' include bioprocesses engineering and energy & fuels engineering, College of Engineering
<http://www.che.psu.edu/Ugrad/index.htm>

Undergraduate Minors:

- Energy Engineering, College of Earth and Mineral Sciences
<http://www.eme.psu.edu/undergrad-minors-options/minor-energyeng.html>
- Global Business Strategies for the Earth, Energy, and Material Industries, College of Earth and Mineral Sciences
<http://www.eme.psu.edu/undergrad-minors-options/minor-globalbusiness.html>
- Energy, Environmental, and Mineral Economics, College of Earth and Mineral Sciences (? In Undergraduate Bulletin but not on EMS site)
<http://bulletins.psu.edu/bulletins/bluebook/minors.cfm?letter=E&program=enec.htm>

Graduate Programs:

- Agricultural and Biological Engineering, Joint offering in College of Agricultural Sciences and College of Engineering-bio-based energy research.

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<http://www.abe.psu.edu/program/grad/program.htm>

- Energy and Mineral Engineering, College of Earth and Mineral Sciences
<http://www.eme.psu.edu/emegrad/index.html>

Extension or Research Programs:

- EMS Energy Institute, College of Earth and Mineral Sciences
<http://www.energy.psu.edu/>
- Earth and Environmental Systems Institute, College of Earth and Mineral Sciences
<http://www.eesi.psu.edu/>
- Penn State Institutes of Energy and the Environment
<http://www.environment.psu.edu/>
- Energy Science and Power Systems, Applied Research Lab
http://www.arl.psu.edu/capabilities/at_esps.html
- Penn State Facilities Engineering Institute, College of Engineering
http://www.engr.psu.edu/AboutCOE/gstudies_psfei.aspx
- Extension's Renewable & Alternative Energy (website)
<http://energy.extension.psu.edu/Default.htm>
- Marine Renewable Energy Capabilities, Applied Research Lab (article)
<http://www.research.psu.edu/iro/events/tradeshows/ebw/brochures/arl-marine-renewable-energy.pdf>
- Energy – Office of Physical Plant (website)
<http://energy.opp.psu.edu/energy-programs>

Appendix D: Inventory of programs in the topic area at select universities

Universities with prominent programs – focused areas in the biofuels, renewable energy, bioprocessing:

State University of New York College of Environmental Science and Forestry (SUNY-ESF)
<http://www.esf.edu/catalog/programs.htm> (April 2009)

Renewable Energy Minor

The development of sustainable sources of energy has become a critical national and global issue due to concerns about the quality and quantity of the different potential resources, energy security, and potential impacts of each on the environment and human health. It is essential that our society and energy professionals gain an understanding of production and conversion of different forms of energy, their current and future supplies, the markets and policy mechanisms that regulate their supply, and the associated impacts on the environment for each fuel. In the past both traditional and renewable energy sources have been studied one resource at a time and usually from the perspective of a single discipline. This minor will provide students an opportunity to examine different sources of traditional and renewable energy simultaneously in the context of our total energy use using a systems perspective. Students will be exposed to views from a variety of disciplines as they wrestle with a wide array of issues related to current and future energy supply and use.

The understanding and development of renewable energy requires expertise from a wide range of disciplines. This minor will be inter-disciplinary in nature with instructors from different disciplines teaching the core courses. The Renewable Energy minor is available to all ESF undergraduate students (**except students who are in the renewable energy option in environmental science**) who have taken EFB 120 Global Environment & the Evolution of Human Society which is a prerequisite for ESC 300 Energy Systems, and have a GPA of 2.750 or better by the end of their sophomore year. Interested students must submit a petition and application form, with courses listed, to their faculty advisor and the undergraduate coordinator of their home department. The petition and application will then be sent to the dean of Instruction and Graduate Studies for final approval. The minor will require a minimum of 15 credits, 12 of which are required courses. The remaining 3 credits can be selected from a list of suggested courses.

Fifteen credit hours of courses are required. Specified courses: ESC 325 Energy Systems (3); ESC 335 Renewable Energy Systems (3); ESC 422 Energy Markets and Regulation (3); ESC 450 Renewable Energy Capstone Planning (1); ESC 460 Renewable Energy Capstone Seminar (2) and a minimum of three credits from the following list of suggested courses: BPE 441 Biomass Energy (3); EFB 516 Ecosystems (3); EFB 518 Systems Ecology (4); ERE 351 Basic Engineering Thermo-dynamics (2); ERE 519 Green Entrepreneurship (3); FCH 360 Physical Chemistry I (3); FCH 571 Wood Chemistry I: General Wood Chemistry (2); FOR 415 Forest-ry Consulting and Wood Procurement (3); PSE 361 Engineering Thermo-dynamics (3); PSE 370 Principles of Mass and Energy Balance (3).

John Brown University in Arkansas

http://www.jbu.edu/news/press_releases/release.asp?id=3050

Renewable Energy Major

Press Release

JBU Announces Renewable Energy Major

Siloam Springs, Ark. (October 28, 2008) – John Brown University is pleased to announce the addition of a Bachelor of Science degree in Renewable Energy beginning fall 2009. JBU is the first university to offer a renewable energy degree in Arkansas and one of only a few U.S. institutions offering a four-year degree in this field.

“Renewable energy sources are becoming an important share of the mainstream energy supply in the United States,” said Fernando Vega, director of the renewable energy program. “Economic, political, and environmental concerns are among the drivers contributing to this rapid growth. The scientific and engineering communities are being pushed for breakthroughs in this area. JBU is developing this program and will be seeking to integrate sustainability topics into other curricula to match the demands of this emerging trend.”

JBU’s program in renewable energy will include courses in wind, solar and biomass energy, practical experience in designing, construction, monitoring renewable energy generators, and possible related study abroad opportunities. Students will choose between one of three focuses within the renewable energy degree: design, management and international development.

JBU’s renewable energy program will study the growing worldwide demand for conservation and energy efficiency, increasing energy costs, environmental benefits of renewable sources of energy generation, climate change/global warming, and its importance as an aspect of Christian stewardship. The program will be an interdisciplinary program that builds on some of JBU’s established programs, including science, engineering, intercultural studies and business.

Dr. Cal Piston, Chair of the Division of Natural Science said, “We are very excited to have a cutting-edge program like this. We have the expertise and experience here to run a great program for students who are interested in entering the field of renewable energy and look forward to an enthusiastic start to the program next fall.”

Those interested in learning more about the details of the renewable energy program at JBU can get detailed information at www.jbu.edu/academics/science/ or by calling 877-JBU-INFO.

http://www.jbu.edu/academics/science/renewable_energy/

Welcome to the Department of Renewable Energy

The Renewable Energy Department of John Brown University offers a Bachelor of Science in Renewable Energy with three options available:

- **Design Option** This option is focused on preparing graduates for technical positions in the energy industry or graduate study in Energy Engineering.
- **Management Option** This option is focused on preparing graduates for positions in business, government, and non-profit organizations in the area of energy management or production
- **International Development Option** This option is focused on preparing graduates to serve domestically or internationally in the arena of community and technological development for NGOs and technical missions work

A [minor in Renewable Energy](#) is also available.

Courses in the Renewable Energy department emphasize laying a strong foundation of the fundamentals of science and energy conversion, its application to international sustainable

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development and the business and management skills to drive its growth market can be effective agents for sustainable change.

The Renewable Energy program is a cross-disciplinary program grounded in the belief that students who understand the fundamentals of science and energy conversion, its application to international sustainable development and the business and management skills to drive its growth market can be effective agents for sustainable change. The Department of Renewable Energy will draw from existing strengths in the Science, Engineering, Business, and the [Institute for Biblical Community Development](#).

Opportunities

Students in the program will study Wind, Solar and Biomass Energy. They will also gain practical experience in designing, constructing and monitoring renewable energy systems. Depending on the option pursued, the senior capstone project will allow students to work directly with local and international organizations doing research, energy assessments and system design.

Careers

Possible careers for graduates of the Renewable Energy Department include:

- Design, integration and sales of renewable energy systems including:
 - Photovoltaic
 - Solar thermal
 - Wind energy systems
 - Biomass systems
- Energy Resource Analyst
- Sustainability Officer
- Community Development Consultant
- Mission Agency Consultant

Illinois State University

http://www.tec.ilstu.edu/renewable_energy/index.shtml

Renewable Energy Undergrad Major

The Renewable Energy undergraduate major is a broad-based program addressing the social, economic, and technical issues that graduates will encounter in the emerging field of renewable energy.

Students will be able to choose between two tracks – a technology track or an economics/public policy track. Graduates will be prepared for jobs in the fields of biofuels, wind and solar energy, or regulatory and governmental agencies.

All majors at Illinois State are built upon a General Education foundation that equips students with communication and critical thinking skills in the context of a global perspective. The Renewable Energy Major is housed in the Department of Technology.

Core Courses: Required by both sequences

- **AGR 225: Renewable Energy and Agriculture**
Explores the relationships between renewable energy and agriculture with emphasis on biofuels, wind energy and hydropower.
- **ECO 105 Principles of Economics**
Supply and demand in product and resource markets, international trade, determination of GDP, employment, inflation and economic growth

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- **ECO 138 Economic Reasoning Using Statistics**
Introduction to descriptive and inferential statistics with applications in economics. Includes the use of statistical software package on laboratory computers.
- **ECO 236 Economics of Energy and Public Policy**
Economic analysis of the production, distribution and use of energy with special emphasis on alternative and renewable energy sources.
- **ECO 239 Managerial Economics**
Theoretical and applied study of demand, cost, and production related to the theory of the firm. Developments of current interest; empirical studies intended to affirm or disaffirm applicability of economic principles
- **GEO 211 Earth's Dynamic Weather**
Dynamic aspects of weather and climate from global to local scales with emphasis on how we gather, analyze, and understand weather information.
- **HSC 156 Environmental Health in the 21st Century: Meeting the Global Challenge**
Application of scientific methods of inquiry to understand environmental problems as they affect public health and personal well-being.
- **MAT 120 Finite Mathematics**
Linear functions, matrices, systems of linear equations, sets and counting, probability, statistics, and mathematics of finance.
- **PHY 105 Fundamentals of Physics**
Concepts and principles of mechanics, heat, wave motion, electricity, magnetism, and light. Applications to everyday life.
- **PHY 207 Energy and Society**
Scientific, technological, environmental, economic, health, ethical, and political aspects of energy production and use, from fossil and nuclear fuels to renewable energy sources.
- **PSY 110 Fundamentals of Psychology**
A review and critical analysis of psychology's most influential explanations of human behavior. Students may be expected to participate in experiments.
- **TEC 111 Fundamentals Of Power Technology**
Principles of electrical, electronic, mechanical, and fluid power components and systems as they apply to industrial applications.
- **TEC 160 Introduction to Renewable Energy Systems**
An exploration of the technologies of renewable energy, emphasizing physical principles and practical applications of wind, solar, and biomass.
- **TEC 270 Managing Technological Systems**
Principles, practices and methods used to plan, organize, lead, and control technological systems.
- **TEC 320 Project Management**
Fundamentals of project management emphasizing planning techniques to meet stakeholder expectations regarding project scope, time, cost, and quality.
- **TEC 360 Renewable Energy Capstone**
A synthesis of the skills and knowledge acquired in the RE major coursework with final project in economic/technology track.

Economics and Public Policy Sequence required courses

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- **AGR 203 Agriculture and the Environment**
Examination of contemporary environmental issues that are strongly linked to current and past agricultural practices.
- **ECO 255 Introduction To Environmental And Natural Resource Economics**
Overview of natural resource and environmental economics. Topics include management of renewable and nonrenewable resources and the economically efficient approach to pollution control.
- **ECO 335 Economics of Regulation and Antitrust**
The origins, aims, methods, and effects of economic regulation and antitrust, with an emphasis on case studies.
- **GEO 205 Living In The Environment**
The human impact on the natural environment. Emphasizes soil, wildlife, forest, mineral and fuel, water and air conservation.
- **POL 232 Politics and Public Policy**
Introduction to the political processes of public policy formation, including theories, and an analysis and evaluation of selected policy areas.

Technical Sequence required courses

- **TEC 240 Electric Circuits And Machines**
Electrical principles and applications including circuit diagrams, switches, relays, motors, and transformers.
- **TEC 263 Automated Fluid Power Systems**
Theory and operation of fluid power circuits and intermediate level PLC (Programmable Logic Controller) programming.
- **TEC 292 Materials Technology**
Introduction to engineering materials, strengths of materials, and standardized testing procedures for determining mechanical and physical properties.
- **TEC 345 Process Control Networks**
Programmable Logic Controller (PLC) programming within process control networks connecting machines, devices, sensors, and computers.
- **HSC 271 Safety Technology or HSC 385 System Safety**

Majoring in Renewable Energy (NY Times, March 26, 2008):

<http://www.nytimes.com/2008/03/26/business/businessspecial2/26degree.html>

March 26, 2008

Majoring in Renewable Energy

By [KEITH SCHNEIDER](#)

AS business and industry are taking more interest in renewable energy, academia is not far behind. Anticipating increased demand for new technical and design skills, colleges and universities across the nation are offering degree programs in the field.

The Oregon Institute of Technology has developed the country's first four-year undergraduate degree program in renewable-energy systems. This year the program is training 50 students and will graduate its first class.

The institute's degree requires basic knowledge in engineering, electrical circuits, motors and generators, thermodynamics, heat transfer and the language of computers. Then come specialized

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courses in photovoltaics ([solar energy](#) research and technology), wind, biomass (the recycling of biological material), hydropower and geothermal energy development.

Robert Bass, 33, the assistant professor who directs the program, said his students would be applying their new bachelor of science degrees in a range of design, engineering, installation, auditing and programming careers in the region's expanding green-power sector.

"We're constantly getting phone calls from renewable-energy companies who advertise jobs," said Dr. Bass, adding that two of his graduating students were already employed full time. "A student graduating from this program has a range of choices about where they want to start their careers. And starting salaries are very good."

Such promising career prospects have helped make the renewable-energy degree the most sought after at the Oregon Institute of Technology's campus in Portland, and similar undergraduate and graduate programs are emerging around the country.

In 2006, the [State University of New York](#) in Canton started a four-year degree program in alternative and renewable energy. In September, Illinois State University in Normal will establish a four-year degree program in renewable energy. Appalachian State University in Boone, N.C., offers an undergraduate degree in appropriate technology, an environmentally and socially responsible approach to engineering, with coursework in the design and construction of solar-powered buildings, drafting, design, woodworking, metalworking, computer literacy, architecture and green construction.

More community colleges are offering one-year certificates and two-year associate degrees in building and installing clean-energy systems. Lane Community College, in Eugene, Ore., trains renewable-energy technicians in a two-year program that teaches students how to improve the energy efficiency of homes and businesses and install solar-power and wind-power systems. San Juan College, in Farmington, N.M., which has a program that specializes in designing and installing solar-energy systems, awards one-year certificates and two-year degrees. Bronx Community College, part of the [City University of New York](#), also offers solar-electric training. Starting salaries nationally, say students and faculty members, typically range between \$35,000 to \$45,000 for graduates of two-year programs and \$45,000 to \$60,000 for graduates of four-year programs.

Renewable energy can be approached from various academic angles, from economics to public policy. "[Stanford University](#) has established several energy and environment research and teaching programs — almost all of these programs are interdisciplinary," said James L. Sweeney, director of the Precourt Institute for Energy Efficiency at Stanford and a professor of management science and engineering there. Stanford emphasized that point this month when it dedicated the \$118 million [Jerry Yang](#) and Akiko Yamazaki Environment and Energy Building, which houses many disciplines in an energy-saving facility.

Nationally, students view these programs as gateways to good jobs. "There's all sorts of stuff out there for us," said Mac Lewis, a 30-year-old student from Cedaredge, Colo., who has a B.S. in chemistry from Mesa State College in Grand Junction, Colo., and is about to graduate with a second degree in renewable energy from the Oregon Institute of Technology.

"We can go into energy auditing, solar design, energy modeling," he said. "There are engineering firms looking for people like me. Photovoltaic manufacturers are coming here. Wind energy companies. There are nonprofit groups that are interested. And that's just what's going on around Portland."

Oregon Institute of Technology

<http://www.oit.edu/kfcampus>

Renewable Energy Engineering

Degree offered: Bachelor of Science in Renewable Energy Engineering

Locations: OIT Portland and Klamath Falls

About our program

The promise of sustainable power depends on our ability to harness renewable resources like wind, sunlight, biofuels, geothermal heat and rivers. The technology needed to harness these natural energy resources is continually improving, but the demand for workers who can lead us toward a sustainable energy future has far exceeded the supply.

Renewable energy is a burgeoning industry, especially in Oregon, where public and private programs and incentives fuel rapid growth. Oregon Institute of Technology has long been an advocate and user of sustainable energy in the region. The Oregon Tech campus in Klamath Falls is the only geothermally heated university campus in America, and is home to the Geo-Heat Center, a national resource for geothermal development. OIT hosts the Oregon Renewable Energy Center (OREC), which conducts applied research on photovoltaic power systems, ground-source heating systems, fuel-cell systems, wind, biomass and integrated systems. In 2005, Oregon Tech furthered its commitment to sustainable power by introducing the first Bachelor of Science in Renewable Energy Systems in North America (now known as Renewable Energy Engineering). Oregon Tech's renewable energy program establishes the engineering principles graduates will need to develop, promote, and implement sustainable energy technologies.

The degree program begins by establishing a solid foundation of physics, chemistry and mathematics, which pave the way for coursework in electrical and mechanical engineering. Upper-division courses in renewable-energy specific courses include photovoltaics, energy management and auditing, wind power, biofuels, renewable-energy transportation systems, green building and fuel cells. The Renewable Energy curriculum prepares graduates for engineering careers in the energy sector in general, and the renewable energy in particular.

Graduates of the program will be prepared for graduate study or for immediate employment as field engineers, energy auditors, renewable energy system integrators for homes and businesses, manufacturing engineers for component and subsystem manufacturers, designers for components and subsystems, local and state government renewable-energy inspectors, planners and other positions in the energy field.

Compiled by Debbie McAllister, Office for Undergraduate Education, February 2008:

- University of Idaho
Biological and Ag Engineering with a Food and Bioprocess Engineering Option
www.agls.uidaho.edu/bae
- University of Illinois
Ag Engineering with specialization in Food and Bioprocess Engineering
<http://www.age.uiuc.edu/ageUndergradPrograms/BSinAgEngineering.asp>
- Purdue

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Biological and Food Process Engineering

<http://www.agriculture.purdue.edu/oap/majorsminors/FoodProcessEngning.asp>

- Iowa State
Ag Engineering with specialization in Food and Biosystems Engineering
<http://www.abe.iastate.edu/academics/agricultural-engineering-undergrad.html>
- University of Kentucky
Biosystems and Ag Engineering with specialization in Food and Bioprocess Engineering
http://www.bae.uky.edu/Undergrad/programs_of_study.htm
- University of Minnesota
Bio-based Products
Bioproducts & Biosystems Engineering
<http://www.bbe.umn.edu/teaching/ugrad/index.html>
www.cfans.umn.edu/bp
- Cornell
Biological and Environ. Engineering with specialization in Food and Bioprocessing Engineering
<http://author.cals.cornell.edu/cals/bee/research/research-foodeng.cfm>
- North Carolina State
Biological Engineering with Bioprocessing concentration
http://www.bae.ncsu.edu/undergrad/bio_eng.htm
- North Dakota State
Ag and Biosystems Engineering with Biosystems Engineering Concentration
http://www.ndsu.edu/ndsu/academic/factsheets/eng_arch/agbiosys.shtml
- Oklahoma State
Biosystems and Ag Engineering with specialization in Bioprocessing and Biotechnology
<http://www.casnr.com/academics/majors/biosystems-and-agricultural-engineering>
- South Dakota State
Ag and Biosystems Engineering with specialization in Energy
http://abe.sdstate.edu/page_a.cfm?page=Academics
- University of Tennessee
Biosystems Engineering
http://bioengr.ag.utk.edu/students/BE_options.asp

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- Virginia Tech
Biological Systems Engineering with Bioprocess Engineering focus
<http://www.bse.vt.edu/06/department/>
- University of Wisconsin-Madison
Biological Systems Engineering with Food and Bioprocess Engineering focus
<http://bse.wisc.edu/programs.html>

Other universities with similar programs – felt that the biofuels, renewable energy, etc. areas were not as focused and rather just a partial component of the coursework.

- Cal Poly
- Auburn
- University of Arizona
- University of Delaware
- University of Florida
- Michigan State
- University of Nebraska-Lincoln
- Ohio State
- Oregon State
- Clemson
- Texas A&M

Appendix E: Science Masters Program Flowchart

