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The Future of UNL Energy Sciences

University of Nebraska Lincoln

*The Future of UNL Energy Sciences * Programs: 2007-2011*

NEnergy

*The term *energy sciences* used throughout this document refers to a broad spectrum of biophysical and social sciences, including the basic sciences (math, physics, chemistry, biology), applied sciences (engineering, agronomy, animal science, architecture, etc.), and social sciences (economics, political science, business administration and development, law)

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The Future of UNL Energy Science Programs[1], 2007-2011

UNL has a large number of faculty conducting research on energy-related topics. However, strategic coordination needs improvement, and there are significant opportunities to leverage synergies across departments and colleges, centers, and institutes. In addition, there are critical gaps in expertise that need filling to achieve critical mass and national prominence in key areas.

This white paper seeks to identify a set of thematic areas that would help focus UNL faculty resources on emerging opportunities in the energy-related sciences and serve as a framework to achieve the following goals:

- Develop innovative research programs that enhance renewable energy resources and energy conservation in Nebraska and worldwide;
- Support economic development in Nebraska through: (i) development of new technologies and commercialization in new businesses, (ii) identification of the most effective policies and incentives at federal, state, and local levels to foster development of renewable energy resources, and (iii) student education and human resource development to support energy industries; and
- Position UNL to be more competitive for external funding from government agencies, private foundations, and the private sector.

The following focus areas are proposed to achieve these goals. These areas were selected based on faculty expertise and interests as indicated in proposals submitted to the competitive grant programs sponsored by the Nebraska Center for Energy Sciences Research (NCESR)[2]. A draft for each focus area was initially developed by a lead group of faculty, which then was presented for a broader discussion at the UNL Interdisciplinary Faculty Retreat held on May 15, 2007. Following the retreat, the focus area descriptions were further refined and submitted to the NCESR Executive Council[3] for review, comment, and final revision.

The seven focus areas include:

1. Catalysis and Metabolic Engineering,
2. Integrated Biorefinery Systems,
3. Carbon Sequestration, Climate Change and Sustainability of Biofuel Systems,
4. 21st Century Power Generating Systems,
5. Energy Efficient Architecture and Environmental Control Systems,
6. Energy Sciences Minor and
7. Analysis, Decision-Making Tools and Outreach for a Sustainable Energy Future.

The NCESR will facilitate further development of these focus areas thorough co-sponsorship of seminars with relevant departments/colleges, by helping identify external funding opportunities, and by working with college Deans and senior UNL leadership to fill key faculty positions.

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[1] Throughout this document "energy science" refers to a broad spectrum of biophysical and social sciences, including the basic sciences (math, physics, chemistry, biology), applied sciences (engineering, agronomy, animal science, architecture, etc), and social sciences (economics, political science, business administration and development, law).

[2] In 2006, there were separate calls for proposals – one for research (which awards $720,000 per year), and another for education (which awards $80,000 per year). Forty-one research proposals were submitted with faculty PIs and Co-PIs from 25 different departments. Twelve education proposals were submitted with faculty PIs and Co-PIs from 18 different departments. A total of 111 faculty were involved in all the proposals. Fourteen research proposals and four education proposals were funded.

[3] The Executive Council mandate is to provide guidance to the NCESR on initiatives and programs in the energy sciences. Members include: John Anderson, Associate Dean - College of Business Admin.; Namas Chandra, Associate Dean - College of Engineering; Gary Cunningham, Dean - Research in the College of Agric. and Natural Resources; Patrick Dussault, Head - Dept of Chemistry, Jerry Hudgins, Head - Dept of Electrical Engineering, and Anne Vidaver, Professor - Dept of Plant Pathology.

Focus Area 1 – **Catalysis and Metabolic Engineering**

Leader(s): Patrick Dussault, Chemistry
Donald Weeks, Biochemistry

Justification

The development and exploitation of new biofuels and chemical feedstocks from agricultural products represent areas of immense opportunity for Nebraska. Although many researchers are investigating new catalysts for oxidation or conversions of existing biofuels (chiefly ethanol, fatty acids and biodiesels), and numerous groups are investigating plant metabolic engineering to achieve or enhance production of designed feedstocks, there has been much less effort to integrate chemical catalysts and processes for use with new or optimized feedstocks derived from metabolic engineering. Similarly, increased biofuel production will almost certainly require increased use of cellulosic and other plant-based feedstocks, calling for modified plant composition and for new catalysts for chemical processing. By coupling the development of new catalysts and new metabolic pathways, Nebraska has an opportunity for integrated development of new biofuel and feedstock production pathways. A major component of this program will be a new integrated lab facility combining a core facility with an adjacent lab space allowing joint experiments by faculty members joining in the activities of the Nebraska Center for Energy Sciences Research.

Funding Sources

The scientific challenges of developing, in parallel, advancements in both metabolic engineering of improved feedstocks and new catalytic systems capable of exploiting those feedstocks, will require fundamental research in biology, biochemistry, and catalytic chemistry, as well as discoveries in applied science at the boundaries of this field. The discovery and development of new commodities based upon the output and byproducts of the new catalytic systems may be another area of opportunity through cooperation with the researchers involved in optimizing the development of integrated biorefinery systems. Likely funding for this research can be anticipated through the United States Department of Agriculture, the National Science Foundation, the Department of Energy, the Department of Defense, and smaller funding groups such as the Consortium for Plant Biotechnology Research. Likewise, the immense practicality of the Center's research in this area may well lead to long-term funding from industrial organizations involved in various aspects of bioenergy and biofuels.

Existing Faculty Expertise:

Catalysis: DiMagno (Chemistry, oxidation catalysis), Berkowitz (Chemistry, ethanol as a biochemical fuel), Blum (Biology, ethanol as a biochemical fuel), Takacs (Chemistry, ethanol as a hydrogen source for chemical conversions), Redepenning (Chemistry, electrocatalysis), Larsen (Chemical and Biomolecular Engineering, catalysis, catalyst stabilization), Noureddini (Chemical and Biomolecular Engineering, catalysis, encapsulation of cellulases).

Metabolic Engineering: Basset (biochemical pathways and manipulations), Clemente (metabolic engineering), Weeks (plant genetic engineering), Fromm (metabolic engineering), McKenzie (energy production in plants), Du (metabolic pathway engineering).

Faculty Expertise Needed

Catalytic chemist: The hiring of a catalytic chemist (for example, a researcher focusing on zeolite or metal oxide based production of fuels or metabolites) is budgeted in the *Alternative Energy* Program of Excellence (PoE). A search is planned for fall 2007.

Metabolic Engineer: A metabolic engineer (for example, a researcher focusing on manipulation of metabolic pathways for production of energy rich compounds.) is budgeted in the *Alternative Energy* PoE with a search planned for fall 2008.

Chemical biologist: A chemical biologist combining expertise in chemical synthesis and biological/biochemical pathways could be a crucial linchpin providing focus for the activities within this group. This position is not yet budgeted in a PoE but is a targeted area of growth by the Department of Chemistry. Examples of research areas that would fit under this rubric include, but are not limited to: (i) the engineering of new biosynthetic pathways to produce value-added products (e.g. J. W. Frost, S. A. Benner, J. Keasling); (ii) the directed evolution or semisynthetic modification of existing enzymes to improve their catalytic performance, substrate specificity, stability or enantiodiscrimination (M. Reetz, R. Kazlauskas, D. Rozzell, B. Jones); (iii) development of new biological catalysts, by combinatorial approaches (S. Miller, S. Lutz, Maxygen, Diversa) or rational design (H. Hollinga, P. Schultz, R. Lerner, K. Janda).

Facilities Needed

Metabolic Engineering and Catalysis Core Facility: A 1,500-2,500 square foot laboratory and adjacent office space (400 square feet) will provide an on-campus “research park” to facilitate cooperative research by members of the Nebraska Center for Energy Sciences Research and associated faculty. The core facility will be configured so as to match the needs of the cooperating faculty members. However, as presently envisioned, the Core Facility is likely to contain a combinatorial robot, a gas chromatography/mass spec unit (GC/MS) for analysis of reactions and byproducts, HPLC and other protein purification equipment, spectrophotometric and other analytical instrumentation, limited hooding or “snorkel” type ventilation, and a high throughput screening facility to accommodate combinatorial synthetic, organometallic and biochemical/enzyme catalysis efforts.

Resources Needed

Faculty position, laboratory/core space, and equipment as described above.

Focus Area 2 – **Integrated Biorefinery Systems**

Leader(s): Milford Hanna, Biological Systems Engineering
David Jackson, Food Science and Technology

Justification

Biofuels are likely to become Nebraska's largest industry within a few years. Currently, the greatest investment is being made in corn grain-ethanol. However, ethanol production from sweet sorghum and biodiesel production from soybean and other oilseed crops are receiving increasing interest. Within a few years, plants will be built to convert cellulosics, such as corn stover and perennial grasses, to ethanol and other chemicals. As biofuel production capacity expands, the amount of co-products will increase (including distillers grains, germ oil, bran, and proteins), which can be used as livestock feed or other industrial bio-based products. Co-products also can be separated into components to produce energy through gasification, biodiesel from germ oil, and cellulosic ethanol from bran. Expanding the range of uses for these co-products is critical for sustainable ethanol production. Some believe that eventually ethanol will be considered the co-product because the greatest value will be derived from non-ethanol products in future biorefineries[4]. A key component of this program will be new lab facilities to house pilot-scale research equipment, which can test and validate the potential for technology commercialization.

Description

A Biorefinery Research Facility is proposed to provide the infrastructure needed to conduct research on feedstocks and fractionation, processing, and conversion to higher value bio-products. Although the initial focus will be given to corn-ethanol and soy biodiesel systems, future efforts might include feedstocks such as sweet sorghum, cellulosic (biofuel) crops, and oilseeds. Pilot-scale equipment will enhance opportunities for collaboration with industry and demonstrate "proof of concept" of new production technologies as well as co-product processing and utilization. The initial facility will include the following components:

- Dry grain fractionation equipment and subsequent processing of fractions;
- Small (3-7 L) and mid-size (60 L) fermentation bioreactors for evaluation of feedstocks and production of samples for feeding trials;
- Enhanced facilities for efficient evaluation of co-product formulation in rations;
- Biodiesel production and co-product conversion equipment; and
- Gasification equipment for converting distillers' grains and other co-products, residues and waste streams into biofuel.

Currently, there are numerous individuals doing research with biorefinery implications, but much of that research is limited to a specific subject and has little influence from other academic or industry perspectives. University of Nebraska - Lincoln faculty are beginning to form relationships in ad hoc ways to combine their knowledge and talents in order to work on bigger issues and from multiple perspectives. Some of the existing, and developing, interdisciplinary Integrated Biorefinery Workgroups include:

[4] In petroleum refineries, the value of co-products (e.g. organic chemicals, plastics) made from oil exceed that of gasoline.

Byproducts characterization and fractionation:
Departments: Biological Systems Engineering, Chemical and Biomolecular Engineering, Food Science and Technology, Industrial Ag Products Center, Animal Science, and Textiles, Clothing and Design
Anticipated Additions; Chemistry and Commodity groups

By-Product Utilization:
Departments: Animal Science, Agricultural
Future Additions: Biological Systems Engineering

Biorefinery Coursework: (Potentially part of Bioenergy Minor)
Departments: Chemical and Biomolecular Engineering, Biological Systems Engineering, Chemistry

Green Chemistry:
Departments: Biological Systems Engineering, Chemical and Biomolecular Engineering, Chemistry, Industrial Ag Products Center, Nebraska Corn Board

Funding Sources
The program is aligned well with DOE and USDA grants programs, and also for collaboration with and funding from industry and Commodity Groups.

Faculty (not intended to be comprehensive)
Agricultural Economics – D Mark, D Connelly, R Perrin;
Agronomy and Horticulture – S Baenziger, T Clemente, D Walters;
Animal Science - G Erickson, T Klopfenstein;
Biological Systems Engineering - M Hanna, L Wang, C Weller, D Jones, Y Yang, J Subbiah;
Chemical and Molecular Engineering - H. Noureddini;
Food Science and Technology - D Jackson, R Flores;
Forestry – S Josiah; and
School of Biological Sciences - P Blum, K Nickerson.

Faculty and Facilities
The future of biorefinery research at UNL will be determined by the ability of faculty to gather and form partnerships to combine expertise, and compete for grants. Group leadership will be a challenge because with all the other teaching, research and outreach activities few people want to take a leadership role in forming or maintaining interdepartmental research groups. Follow-up sessions will be conducted to develop lists of existing faculty expertise and facilities and to develop lists of needed expertise and facilities.

Focus Area 3 – **Carbon Sequestration, Climate Change and Sustainability of Biofuel Systems**

Leader: Shashi Verma, Natural Sciences

Justification

Atmospheric carbon dioxide (CO_2) levels have been steadily rising because of increased use of fossil fuels and expansion of extensive, low input agriculture in the tropics and subtropics of Asia, Africa, and South America. These trends contribute to global climate patterns and can have negative impact on ecosystem services. One way to mitigate the increase in CO_2 is to remove it from the atmosphere by increasing the amount of carbon (C) stored in terrestrial ecosystems - so called "carbon sequestration." Biofuels can also help mitigate greenhouse gas emissions (GHG) and reduce our dependence on petroleum-derived gasoline and diesel motor fuels. Expansion of biofuel production has strong support from the general public and major environmental organizations. This support is based on the belief that crop production capacity will be sufficient to meet feedstock needs without a large rise in consumer food prices and that biofuels have a net positive impact on environmental quality and climate change. Continued public support and federal tax incentives therefore depend on greater scientific clarity about these benefits. Key scientific challenges that must be addressed are: (1) accurate quantification and prediction of C sequestration in biofuel cropping systems and the relevant controlling factors, (2) an acceleration in the rate of gain in biofuel crop yields to meet the growing demand for food, livestock feed, and biofuel while concomitantly protecting water and soil quality and achieving a net reduction in GHG emissions, and (3) use of the tremendous volume of co-products in a cost-effective and environmentally sound manner. This program will provide national and international leadership in these research areas.

Description

Research would focus on developing fundamental understanding of carbon, energy, nutrient, and water cycles in major biofuel cropping systems to help achieve environmental sustainability. Such research requires an "ecosystem-level" approach and production-scale facilities to obtain realistic data on how innovative cropping systems, biofuel plants, livestock feeding operations, and bio-processing facilities influence food and feedstock supply and environmental impact. The goal is to better understand and predict the amounts of C sequestered, and the impact of current and emerging technologies on GHG emissions and net global warming potential to allow regional, national, and global extrapolation of results. UNL is a major land grant university with both the production-scale research facilities and faculty expertise for this type of research. Economists would utilize the data from the life-cycle analyses to identify the most cost-effective options for ensuring both adequate food and feedstock supply while protecting environmental quality and contributing to a net reduction in GHG emissions.

Funding Sources

The scientific challenge to predict C sequestration in an accurate and verifiable manner and to expand biofuel production while avoiding high food prices and protecting the environment has been underestimated. Likewise, there are growing concerns about the environmental and economic sustainability of biofuel systems. Therefore, we expect these concerns to result in major new research initiatives funded by DOE (C-Cycle Research Centers), EPA, and USDA.

Faculty Team Members

K. Cassman, D. Walters, S. Baenziger, W. Schacht, C. Wortmann - Agronomy & Horticulture.
G. Erickson and T. Klopfenstein - Animal Science.
S. Verma, A. Gitleson, E. Walter-Shea, K. Hubbard - School of Natural Resources.
K. Vogel, W. Wilhelm - USDA-ARS.
J. Knops - School of Biological Sciences.
S. Madhavan - Biochemistry.
Plant pathologist (to be determined)

Resources Needed

Faculty Positions: Ecosystem Modeling, Tower Flux Measurement and Analysis, Cropping Systems, Biochemistry-Biofuels, Carbon Economic Modeling, and industrial ecology.

Resources to establish tower eddy covariance measurement systems and associated crop and soil measurements in production scale fields for major biofuel crop options.

Focus Area 4 – **21st Century Power Generating Systems**

Leader(s): Jerry Hudgins, Electrical Engineering

Justification

World electricity demand is expected to grow by more than 3% annually through 2020 (2% annually in US to 5 Trillion kWh). World consumption of fuels (87% of consumption projected to be fossil fuels) is expected to increase by 60% over that time as well[5]. The US energy flow indicates that 41% of energy sources are used for electric power production. This electrical power is then primarily delivered to residential/commercial and industrial users. Over 29% of total energy sources are used for transportation applications[6]. It is clear that electric power production and transportation power are the top demands for our energy.

Natural gas prices have risen dramatically in recent years as demand has increased substantially. Future mandatory limits on atmospheric CO_2 release are expected to have a major impact on electricity production. Advanced coal, nuclear, natural gas, and renewable (primarily wind and some solar) sources will provide the majority of power production in the world this century. Power providers will likely diversify to build a strategically balanced power portfolio. Other factors such as distributed and interconnected generation sources, and grid security will also affect investment and capitalization by power providers. Technologies further out on the horizon may have impact later this century. These include development of hydrogen for small power production (stationary and mobile) and other biological sources (*e.g.* microbial fuel cells).

Description

This program will focus on frontiers of energy generating systems that are substantially more efficient than today, reduce greenhouse gas emissions, provide a stable and secure grid, and meet market demand for a distributed energy supply. A part of the power production technology frontier is related to energy storage, particularly electrical energy storage, including batteries and fuel cells. Another storage hurdle relates to hydrogen, principally for mobile (transportation) applications. Efficiencies are to be gained at all levels from advanced power plant design and operation to advanced solar cells, fuel cells, electric machines, and power electronics systems. Optimization, new chemistries, and new materials will contribute to power sub-system components such as electrolyzers, batteries, fuel cells, and wind turbines. Specific research topics include:

- Hydrogen production from wind sources
- Microbial fuel cells
- Power plant efficiency (Co-generation)
- Micro fuel cells
- Battery technology
- Combustion Technologies for CO_2 Reduction
- Policy Enhancement related to Generation
- Combustion Kinetics of Ethanol & Other Fuels
- Ultra-efficient electric machine design
- Series hybrid vehicle designs
- Solar cells
- Hydrogen storage
- Wind for irrigation
- Other Energy Storage
- Nanostructures for Fuel Storage
- Public Education Programs

[5] *International Energy Outlook 2002*, Energy Information Administration, Table A-2 and A-9, p. 181 and 188

[6] *Annual Energy Review 2001*, Production and end-use data from Energy Information Administration.

Funding sources and opportunities

This focus-area is aligned well with funding sources at DoD, DOE, EPRI, USDA, NSF, and many varied industrial concerns. There are opportunities to partner with industry to affect policy changes to enhance economical adoption of new power generation technologies. Other opportunities exist in the arena of public education and outreach programs related to power generation technologies.

Faculty

Biological Systems Engineering	Ron Yoder David Jones Milford Hanna
Civil Engineering	David Admiraal Tian Zhang
Electrical Engineering	Jerry Hudgins Dean Patterson Sohrab Asgarpoor Ned Ianno Rod Soukup
Engineering Mechanics	Li Tan
Mechanical Engineering	Zhaoyan Zhang George Gogos John Barton Jeff Shield David Lou
USDA-ARS	Dan Miller

Faculty Expertise Needed

- Electrochemistry for energy storage (battery, capacitor, and fuel cells) and electrolyzers
- Nuclear chemistry for fuel processing, fuel reliability, and fuel re-processing for advanced reactors and waste disposal
- Hydrogen storage
- Hydrocarbon reformers for Polymer Electrolyte Membrane (PEM) fuel cells

Focus Area 5 – **Energy Efficient Architecture and Environmental Control Systems**

Leader(s): Wayne Drummond, Architecture
Bing Chen, Computer & Electronics Engineering

Justification

Over the short-term, energy conservation represents the greatest source of "new energy" because it is possible to greatly reduce energy requirements for residences; office buildings; and commercial, healthcare, research, institutional, agricultural and industrial facilities through improved architecture, material technologies, the incorporation of renewable energy strategies, optimized heating and cooling system design and controls, and community planning and development. The intent is to bring together faculty expertise in the appropriate disciplines to create a coordinated and nationally recognized program in these areas.

Description

Since the passing of the solar access bill during the Thone administration, few communities have taken advantage of the opportunity to plan housing developments that will significantly reduce energy requirements. A wind conference hosted in 1996 by the University of Nebraska's College of Engineering and the Nebraska Energy Office resulted in several wind generators being installed, but total wind generating capacity remains far below the 1,000 MW identified in a Union of Concerned Scientists study of Nebraska. No comprehensive energy plan or energy mandates have been developed by the state for residential and commercial institutional and industrial buildings. Cities across the nation are adopting energy and "green building" standards regarding the performance and sustainability of the built environment. European countries have established these goals as national priorities. At the University of Nebraska, conservation and renewable energy research has been piecemeal and not part of any integrated planning effort. The University of Nebraska system should become a model of sustainability. The consumption of all resources, including water, is directly related to the principles of sustainability. Clearly, there is a greater concern being evidenced with respect to global warming, escalating natural gas and oil prices. A longer term plan to curb energy and water usage by all sectors of society has yet to be developed.

A *Sustainable Buildings Energy Center* (SBEC) could focus and serve to coordinate individual researchers and entities within the University to develop the following elements: 1) Identify faculty resources currently involved in energy conservation and those interested; 2) Create a Sustainable Building Energy Center; identify potential funding sources and review the current state of the art in other states and countries; 3) Identify and bring in experts in energy conservation and renewable resources to assist in the planning and development of the Center; 4) Develop a comprehensive program for conservation and renewable resources for UNL and potentially the NU System to include a timeline and budget; 5) Identify building industry, community and governmental bodies that could serve as partners and sponsors; 6) Collaborate with European and other international entities that are active in conservation and renewable; 7) Develop an outreach program to communities and cities in energy conservation (building energy workshops conducted around the state); 8) Produce an updated version of the 1981 *Nebraska Passive Solar Primer* which led to 1,000 homes being retrofitted or built with solar-conservation design; 9) Develop a commercial/industry program in concert with the Nebraska Energy Office and utilities that could research new areas such as controls for heating, ventilation and air conditioning (HVAC) and lighting strategies, off peak electric load mechanisms, improved fan coil motor systems and insulated building panels; and 10) Develop public policy standards for the sustainability of the built environment.

Funding Sources and Opportunities

Nebraska Energy Office, Department of Energy, National Renewable Energy Laboratory, Nebraska Investment Finance Authority, Omaha Public Power District, Lincoln Electric System, Nebraska Public Power District, American Society of Heating, Refrigeration and Air-Conditioning Engineers, American Institute of Architects, American Planning Association illumination companies, HVAC equipment manufacturers and building materials manufacturers.

Faculty

Architecture	Wayne Drummond
Architecture Program	William Borner Duncan Case Nate Krug Sharon Kuska
Architectural Engineering	Gregor Henze Haorong Li Mingsheng Liu
Biological Systems Engineering	Dennis Schulte Jeyam Subbiah Wayne Woldt
Computer & Electrical Engineering	Bing Chen Song Ci Hamid Sharif
Electrical Engineering	Jerry Hudgins Dean Patterson
Environmental Safety (UNO)	Patrick Wheeler
Physics & Astronomy	Christian Binek David Sellmyer Ralph Skomski
Textiles, Clothing & Design	Shirley Niemeyer

Other Faculty

(to be determined)

Faculty Expertise Needed

Building design and energy conservation, controls, optimization, public policy, city and regional planning, development, transportation and public infrastructure.

Focus Area 6 – **Energy Sciences Minor**

Leader(s): Ron Yoder, Biological Systems Engineering
Steering Committee: Ron Yoder (Chair), Dennis Conley, Jerry Hudgins, Jack Schinstock, Shashi Verma, Dan Walters, and Adam Liska

Justification
The Energy Sciences Minor will provide an exciting opportunity for students to learn about the capture, production, storage, and utilization of energy, and the associated choices societies must make related to environmental and economical tradeoffs. The minor is structured to attract non-science and science majors and will be offered in all colleges in the university that choose to participate. The minor comprises three introductory core courses (totaling 9 hrs) that will provide a comprehensive overview of energy in society, fundamental energy principles, the economics of energy, and environmental issues related to producing and using energy. These courses will encourage student involvement from a broad range of backgrounds. The core courses will be highly interdisciplinary, particularly the first and third courses. In addition to three core courses, a set of three to five upper-division, discipline-oriented elective courses will be developed for each of four thematic areas: i) **Energy and Natural Resources**, ii) **Plant and Animal Bioenergy**, iii) **Energy Engineering**, and iv) **Energy Economics, Policy, and Human Dimensions**. There also will be three additional 1-unit "enrichment" courses as part of the minor, including a lecture series and field trips. A total of 18 hours of courses will be required for fulfillment of the minor.

Description The core courses of the Energy Sciences Minor include:

1. ENSC 101: ***Energy in Perspective***

Course description—This course will focus on energy flows at the surface of the earth and how humans have harnessed these sources throughout history, from primitive societies to our current global society, to provide the necessities for human survival and to improve the level of human existence by developing industry; renewable energy sources will be explored. A broad multidisciplinary perspective will be employed to combine historical and sociological analysis and interpretation with scientific principles to place energy production and use in the context of societal, economical, political, international relation, and environmental considerations. The presentation of scientific principles associated with energy will be interwoven with the topics under discussion, and the course will be designed to motivate students to continue to explore important energy issues.

Outline—The course will be divided into four parts: (1) **Current energy issues:** growing population and demand, national security, climate change, and energy use in the US with international comparisons, (2) **Primitive societies**: including development of agriculture and scientific aspects of energy flows in agriculture and human nutrition, (3) **Fossil fuels in society:** industrial revolution, development of oil resources and transportation, international conflicts, and relationships between energy consumption and standard of living around the world; related scientific topics will include the carbon cycle, the global climate, and the functioning of fossil fuel systems (continued in the second core course), and (4) **Renewable energy:** potential benefits of utilizing renewable energy, sources, economical and environmental trade-offs, and limitations to implementation (continued in the third core course), and scientific aspects including the functioning of renewable energy systems (continued in the second core course).

2. ENSC 102: ***Introduction to Energy Systems***

Course description—This course will explore the exposition of all sources of available energy, the geographic distribution of energy sources, estimated recoverable amounts, the transformation process for converting source energy into high-quality energy in other forms, and future expected energy demand. The sustainability of these systems and other trade-offs (economical, environmental, and technological) will be explored, along with the relationship between power production and water resources. Energy sources that will be explored include: petroleum and other fossil fuels, biomass conversion products (ethanol, methane, etc.), wind, solar, other renewables, hydrogen, and nuclear. Topics related to the efficiency of commercial buildings (heating, cooling, and lighting), residences, personal transportation, and personal electric usage will be introduced and discussed in the context of other constraints. Related issues of energy storage will also be discussed. (Note: This course is already a requirement for electrical engineering students and will be further developed for the minor.)

2. **ENSC 103: *Energy Economics and the Environment***

Course description—This course will explore energy markets, natural resource use, and the associated environmental trade-offs involved in the implementation of conventional and renewable energy systems. The course will address the same energy systems that were discussed from a technical perspective in the second core course, and will be developed by a team of ecologists and economists building on courses in natural resource economics, ecological economics, and climatology. Scientific topics such as climate, efficiency, and environmental impacts will be addressed.

The elective for the Energy Sciences Minor include:

The four elective specializations will contain three to five courses, which are yet to be developed with participating faculty. Examples of possible course topics include (by section):

i) Energy and Natural Resources: climate (SNR), water quality (Agro/BSE) and quantity (SNR/BSE), fossil fuels reserves (Geol), biogeochemistry (Geol/SNR), and forestry (SNR);

ii) Plant and Animal Bioenergy: biomass production (Agro), biotechnology (Agro/Bio), animal systems (AnSci), agricultural energetics (Agro/Eng);

iii) Energy Engineering: wind, solar, biofuels (Eng), environmental controls (Eng), and architecture (Arch);

iv) Energy Economics, Policy, and Human Dimensions: biofuel economics (AgEcon), environmental law, policy development, regulatory choices, and business (CBA).

Administration and Implementation of the Minor

Timeline: The first and second core courses will be offered beginning in fall 2008 (in the Undergraduate Bulletin, spring 2008). The third core course will be offered beginning in the spring 2009. Electives will be offered as they are developed (the first ones no later than fall 2009); some are currently taught as exploratory courses (e.g., biofuels and water quality, biofuel economics).

Workshop: Additional input from interested faculty will be gained from a workshop in August 2007.

Participating colleges: College of Agricultural Sciences and Natural Resources, College of Engineering;

Likely participants: College of Arts and Sciences, College of Education and Human Sciences, College of Architecture, College of Business Administration.

Curriculum committees: The minor will be presented to the University Curriculum Committee in October 2007.

Focus Area 7 – **Analysis, Decision-making Tools and Outreach for a Sustainable Energy Future in Nebraska**

Leader(s): Sandra Scofield, Nebraska Rural Initiative
Mark Hoistad, Architecture

Justification: Nebraskans are confronted with multiple, complex decisions as we move into a rapidly changing era of renewable energy development. There is a need to analyze existing data, coordinate resources, create decision-making tools, and design and implement outreach programming to ensure wise choices are made for the future**.** The national emphasis on renewable energy sources creates major opportunities and challenges for states like Nebraska. Energy resources must be maximized for economic and environmental benefits while avoiding unintended consequences of rapid and changing development. The complex interrelationships of a growing renewable energy sector are not well understood either from a physical infrastructure perspective or the social and economic implications of shifts from a predominantly fossil fuels based energy economy. There is also a need to assist Nebraska energy entrepreneurs in assessing and evaluating opportunities to develop various alternative energy businesses.

The impact of corn based ethanol development ripples across a variety of sectors and creates a complex web of new relationships. Current understanding of these linkages is largely anecdotal. Communities, counties, utilities and state governments are asked to invest in highways, increased electrical transmission capacity and workforce development to support this emerging industry with little or no long term analysis and in the absence of decision support tools. For example, one Nebraska community of 3,000 residents reports it spent $500,000 to install additional natural gas lines to support a new 100 million gallon ethanol plant. That same community must find 400 acres to offset additional water requirements. Another community of only 1,000 residents committed in excess of $10 million over the next decade in tax increment financing. As numerous other plants spring up across the state and in neighboring states, the question of long term profitability hinges on the price of corn, the continuation of federal and state subsidies, and the state of emerging science.

As the science evolves, policy support for other renewable energy sources beyond corn-based ethanol, such as cellulosic ethanol, biofuels and bio-gas production, may create competition that threatens communities who have become dependent upon ethanol. At the same time, the next generation of discovery is likely to create new opportunities for investment and start another cycle of demands on public investments. Speculation about the impact of rising food prices has created other controversy as have concerns about available water and the impact on air quality and general quality of life. Various communities engaged in ethanol development report an increase in both truck and train traffic to the point of raising concerns about road maintenance, noise, air quality, safety and quality of life. Hundreds of vendors service the plants thus creating economic development opportunities yet workforce shortages are common. Decisions made in this rapidly changing context may commit public resources for a decade or longer. Therefore, citizens and decision makers require unprecedented levels of timely and reliable information and assistance from multiple disciplines to successfully navigate these turbulent times.

Description: This interdisciplinary effort brings a team of experts from the natural sciences, engineering, computer science, architecture, business and finance together with social scientists, experts in policy and public affairs and educators. In order to assist Nebraska citizens and decision makers in identifying and evaluating options that lead to informed choices about a sustainable energy future, this team will analyze issues, organize inventories, map resources, conduct case studies, develop a decision support tool, and design and implement a statewide outreach program. The outreach program will ensure the most current research and information are translated and delivered in understandable and accessible forms for the benefit of decision makers and practitioners. State and federal agencies, Nebraska Public Power District and other utilities, community and state stakeholders and decision makers will be engaged as partners. While the development of these tools is intended to first benefit Nebraska, they will also be relevant in other states and to national decision makers.

Funding Sources: USDA, DOE, NSF, private foundations such as Kellogg, state government and possibly industry partners.

Faculty Expertise:

Architects, Community & Regional Planners: Bill Borner, Wayne Drummond, Mark Hoistad, Yunwoo Nam, Gordon Scholz.

Communication Studies & Leadership Studies*:* Kristin Lucas, Dan Wheeler

Economists, Business and Finance: John Anderson, Brad Lubben, David Peters; Bureau of Business Research, Eric Thompson; Center for Entrepreneurship, Glenn Friendt

Extension: Rick Koelsch, Biofuels Faculty Team

Engineers and Computer Scientists*:* Elizabeth Jones, Erick Jones, Ray Moore, Larry Rilett (Nebraska Transportation Center), Rick Sincovec.

Sociology, Psychology, Law, Policy and Public Affairs: Randy Cantrell, Mary Hamilton (School for Public Affairs-UNO), Alan Tomkins, Sandy Scofield.

Water, energy, soils and crop production: Water Center; Ken Cassman, Center for Energy Science Research; Paul Read, Charles Wortmann (Agronomy & Horticulture)

Others: Yiqi Yang (TCD), Evelyn Jacobsen (Humanities), Aaron Price (student).

Faculty Expertise Needed: Additional faculty from fields such as political science, law, energy sciences, agriculture and extension will be recruited from existing faculty. Longer term needs have been identified for an environmental planner and faculty with expertise in sustainability, particularly in the public finance arena relative to economic development programs. These might be drawn from various disciplines. Expertise is needed to increase the recognition of the significant UNL knowledge base in these topic areas, which is not always well recognized off campus. Some key people are nearing retirement in Architecture and Community and Regional Planning and probably other fields above not yet identified. Long term planning will require filling of key positions as retirements occur.

Resources Needed: The primary needs will be release time to allow for the extensive engagement, research and collaboration such an ambitious multidisciplinary effort will require. Staff to coordinate and support this work will also be required, including Extension and outreach personnel. There may be needs to purchase data bases and software but these are yet to be determined. Resources to address the key issue of how to engage research and extension faculty in collaboration on areas of common interest are needed. Likewise, there is an opportunity to share resources with Group 2 - *Integrated Biorefinery Systems*, Group 3 - *Carbon Sequestration, Climate Changes and Sustainability of Biofuel Systems* and Group 5 - *Energy Efficient Architecture & Environmental Control Systems*, particularly in the outreach and extension area. A central location to facilitate the collaboration among faculty would also enhance this complex process.