University of Nebraska Lincoln

Nebraska Center For Energy Sciences Research

2006/07 Energy Research Grants

NCESR. The Nebraska Center for Energy Sciences Research (NCESR), a collaboration between the Nebraska Public Power District (NPPD) and the University of Nebraska-Lincoln (UNL), was established in April 2006 to conduct research on renewable energy sources, energy efficiency and energy conservation; and to expand economic opportunities and improve quality of life for Nebraska and the nation.

Goal. The overall goal of the NCESR is to foster research and education in energy sciences by providing funding to support innovative research and collaboration among University of Nebraska-Lincoln faculty and other public- and private-sector organizations and businesses working in energy sciences.

RFP. The NCESR released the Request for Proposals (RFP) for its first competitive rounds of Energy Research Grants on July 18, 2006.

Proposals. Interest was high and the competition was fierce in this first year. UNL faculty submitted 41 proposals with $2.2 million in total requested funding for an allocation pool of $720,000 by the proposal deadline of September 8, 2006.

Categories. The 41 proposals were grouped into the following categories:

1. Bioenergy Conversion Processes:
   - 1a – genomics, biochemistry, catalytic chemistry
   - 1b – chemical and industrial engineering
2. Physics; electrical, mechanical engineering (non-biofuel)
3. Architecture; architectural engineering
4. Agriculture, agronomy, animal science, agriculture meteorology
5. Economics, policy, feasibility studies

External Review. A team of highly qualified, external reviewers conducted a rigorous review and evaluation of the proposals on September 21 and 22, 2006.

Selection. The External Advisory Committee (EAC) of the Nebraska Center for Energy Sciences Research (NCESR) met on October 18, 2006 and selected 14 project proposals for funding in its first competitive round of Energy Research Grants offered to faculty at the University of Nebraska-Lincoln (UNL).

06/07 Funding. Of the 14 selected, the EAC placed special conditions on 7 of these projects, several of which the final funding level was determined in November and December 2006. The final funding for the 14 projects for the first year only totaled $719,649.

Second Year Funding. To maintain funding for a second year, all projects are required to submit a six-month and 12-month progress report that provides enough detail to determine whether progress is sufficient to justify continued funding.

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Category 1a: Bioenergy Conversion Processes – genomics, biochemistry, catalytic chemistry

1. *Ethanol as an Energy Source and Terminal Reductant: Exploitation of Thermophilic Redox Enzymes in Catalyst Development and Screening*

Principle Investigator: David Berkowitz, Chemistry
Co-Investigator(s): Paul Blum, School of Biological Sciences

http://chem.unl.edu/faculty/eachfaculty/berkowitz.shtml

The project is a new collaboration between a synthetic organic chemist (Berkowitz) and an archaebacterial enzymologist (Blum) that aims to develop the biotechnological potential of thermophilic alcohol dehydrogenases for practical applications in energy transduction and asymmetric synthesis. The research seeks to define fundamentally new applications for ethanol, and provide new biotechnology opportunities for bioethanol producers.

The long term goals are to create new technologies for ethanol as the terminal reducing agent for the production of high value organics, and to provide a new tool for catalytic evolution of hydrogen from ethanol.

The Principal Investigators come at the science from entirely different disciplinary points of view in this first opportunity for collaboration. Significant dividends at the chemistry/biology interface are expected.

Category 1b: Bioenergy Conversion Processes – chemical and industrial engineering

2. Improving Ethanol Production Efficiency: Optimization of Corn-based Feedstock Energy Conversions

Principle Investigator: David Jackson, Food Science & Technology
Co-Investigator(s): Wajira S. Ratnayake, Food Science & Technology
Rolando A. Flores, Food Science & Technology
Galen Erickson, Animal Science

http://foodsci.unl.edu/Faculty/jackson.cfm

The project seeks to increase ethanol production efficiency using corn-based feedstocks, while maintaining high-quality cattle feed byproducts.

Corn ethanol production processes can be divided into three major stages: input/raw material processing, fermentation, and product/byproduct separation and processing. The project plan is to alter raw material (feedstock) processing prior to fermentation by introducing new dry-fractionation and fraction separation techniques. This will increase overall process efficiency by diverting feed byproducts from the fermentation step. This will increase overall process efficiency by diverting feed byproducts from the fermentation step. In addition, thermal pre-processing will be optimized to impart only the minimum starch modification/cooking necessary to ensure enzymatic digestion. The fermentation process step will also be improved by determining the optimal process conditions to increase ethanol yield. Thermal energy requirements and processing times will be reduced by exploring techniques that allow direct fermentation of starch by yeast. As production practices are evaluated, the energy inputs and ethanol plus byproduct outputs will be measured to ensure high yields and economic efficiency, including measuring the relative feed-quality of byproducts.

Infrastructure will also be developed at the University of Nebraska-Lincoln to evaluate and optimize grain and cellulose inputs, and generate critical data on novel ethanol production processes.

3. Ethanol: Utilization of By-Products

Principle Investigator: Hossein Noureddini, Chemistry & Biomolecular Engineering

http://www.engineering.unl.edu/academicunits/chemical-engineering/faculty/noureddini.shtml

Fuel ethanol production is one of the fastest growing industries in the United States. The current production of ethanol relies predominantly on starch and sugar-based material which primarily use energy crops, such as corn or sugar canes. The potential for the starch and sugar-based products as raw material for ethanol production is limited. Future expansions in the ethanol industry will ultimately need to rely on lignocellulosic substrates if significant share of the 100+ billion gallons per year of the gasoline market is to be realized. One of the major technical areas set in the Biomass R&D Act of 2000 as amended by the Energy Policy Act of 2005 is “Overcoming recalcitrance of cellulosic biomass through developing technologies for converting cellulosic biomass into intermediates that can subsequently be converted into biobased fuels and biobased products. This project is aimed at developing technologies for the conversion of cellulosic biomass to ethanol. The raw material used in this research will be the by-products from the existing ethanol industries (corn based) and use of these cellulosic materials for the production of fermentable sugars. However, the developed technology with these substrates will be equally applicable to other bio based material such as switch grass, corn stover, and other cellulosic residues.

The main focus of this research proposal is to utilize the by-products from the existing corn-based ethanol facilities, mainly DDGS and CGF. This utilization is envisioned as a refining process for these by-products which may result in a variety of marketable products including ethanol. The specific objectives are listed below:

1. Comprehensive analysis of the streams that are combined to form the by-products. This will include the beer bottom, thin stillage, steep water and corn fiber. Other streams that result from the separation steps (Objective 2) and hydrolysis steps (Objective 3) will also be analyzed and evaluated for their potential in the formulation of marketable products.
2. Separation of non-carbohydrate compounds such as lignin, oil, and protein from DDGS and corn fiber prior to or parallel with acid and enzymatic hydrolysis of the carbohydrate components of these compounds.
3. Utilization of a stage wise dilute acid and enzymatic pretreatment scheme for the hydrolysis of the refined DDGS and corn fiber streams to fermentable sugars with more than 20% sugar concentration.

4. Technical and Economical Analyses of Combined Heat and power Generation for Distillers Grains

Principle Investigator: Lijun Wang, Biological Systems Engineering

 http://bse.unl.edu/about/Faculty/Wang.htm

Funds were provided to this Principle Investigator to attend meetings and conferences to learn more about this subject matter and to work toward developing a more comprehensive proposal for the next cycle of research grants.

5. A Prototype Series Hybrid Drive Train Using New Permanent Magnet Electric Machine Designs

Principle Investigator: Dean J. Patterson, Electrical Engineering
Co-Investigator(s): Jerry L. Hudgins, Electrical Engineering

patterson@ieee.org

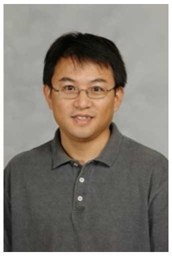
This project aims to produce a small plug in electric hybrid vehicle whose performance will approach very closely the optimal possible, in terms of energy efficiency, for passenger road vehicles. This efficiency will be significantly higher that of currently commercially available hybrid vehicles, whose structure is has been necessarily constrained to what could be considered viable and acceptable in the larger market place. The resultant vehicle will give particularly high visibility to energy research at UNL, and will be significant nationally.

The project will:

1. Demonstrate the efficiency gains to be had (through mileage improvement) by using a full series hybrid topology in a small passenger vehicle,
2. Incorporate advanced battery systems for energy storage, and
3. Develop a battery charger module that will enhance the introduction of plug-in hybrid vehicles.

6. *Rapid Screening Micro Fuel Cells for Portable Electronics*

Principle Investigator: Li Tan, Engineering Mechanics



http://www.unl.edu/emhome/faculty/tan.html

The goal of this project is to design and develop a platform for rapid screening fuel cells suitable for portable electronics. The project will deliver a systematic survey on micro fuel cell structure – material – performance relationship; and a batch fabricated multi-element fuel cell array and corresponding operation and data collection system.

The objective is to demonstrate the following: (1) An infrastructure built upon MEMS (Micro-Electro-Mechanical System) technology; and (2) a simple and reliable system bridging the gap between fundamental fuel cell research and applications. Current micro fuel cell research is hampered by insufficient data on their structure and properties and by lack of high-throughput optimization methodologies. The approach is targeted to fill those gaps.

7. Magnetic Nanostructures for Energy-Efficient Cooling

Principle Investigator: Christian Binek, Physics & Astronomy

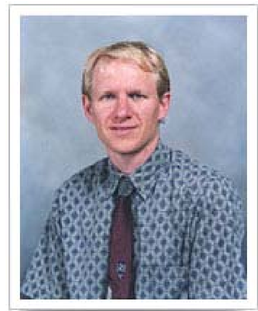
http://www.unl.edu/ncmn/faculty/binek.shtml

The primary objective is the realization of the highest efficiency magnetic refrigeration technology based on the design and fabrication of novel nanostructured metamaterials. Magnetic refrigeration uses field-induced manipulations in the spin order of magnetic materials. Controlling the magnetic entropy contribution in a cyclic process gives rise to a periodic temperature decrease of the magnetic material which can be used for cooling appliances analogous to a gas-compression process in conventional refrigeration technology. However, in contrast to the latter, magnetic refrigeration enables cooling efficiencies which are by far greater than conventional gas-compression refrigeration. This technology combines the significant influence on energy conservation with an environmentally friendly operation mode where ozone-depleting chemicals are absent.

The work focuses on tailoring new materials which allow transferring this performance to room temperature and into a moderate magnetic field regime achievable by strayfields of industrial permanent magnets. To realize this performance novel, metamaterials based on nanoparticle systems and artificial heterostructures are designed and grown by modern molecular beam epitaxy and cluster deposition techniques. Advantage is taken of the investigators expertise in nanothermodynamics, magnetic nanostructures and novel nanotechnologies. Nanostructured materials are superior to bulk materials when tailoring fundamental properties such as the magnetic moment per particle, intra- and interparticle as well as intra- and interlayer exchange in nanoparticle and multilayer systems.

8. *Flow Measurement of Power Plant Water Resources and Discharges Using Thermal Imaging*

Principle Investigator: David M. Admiraal, Civil Engineering



http://www.engineering.unl.edu/civil/faculty/admiraal.shtml

Over the past few years, thermal imaging cameras have become increasingly sensitive, more accurate, and less costly. There are many possible applications for these cameras associated with rivers and water bodies. The application proposed herein is to use the cameras to track the motion of thermal structures on the surfaces of rivers and canals. As the sensitivity and resolution of thermal cameras increases, the ability to track these thermal structures is also improving, with the result that tracking the motion of an entire water surface is now within our grasp. We are proposing a project in which we will explore the use of thermal imaging techniques to track thermal structures in the vicinity of power generation cooling water intakes and discharges. The cooling water discharges will provide plumes of warm water that can be tracked with a camera mounted on an aircraft. Algorithms for converting thermal images into velocity distributions will be developed and evaluated for thermal structures of various scales. Proposed laboratory and field measurements will define the capabilities and limitations of using thermal imaging for measuring water surface velocity distributions. In addition, where possible, the method will be extended to include flows that do not have warm water plumes (e.g., cooling water intakes and streams). The resulting techniques and tools will be extremely useful for a wide range of hydraulics applications that are beneficial to the energy sector and to any other entities for which surface water flow measurements are important.

9. Hydrogen Production and Storage Using Wind and Nuclear Sources

Principle Investigator: Jerry L. Hudgins, Electrical Engineering
Co-Investigator(s): Sohrab Asgarpoo, Electrical Engineering
Dean Patterson, Electrical Engineering

http://ee.unl.edu/people/hudgins.html

Low-cost hydrogen production in a residential or small rural environment will help achieve DOE's cost and production goals, and further implementation of the hydrogen economy. Integration of power electronics sub-systems between a wind turbine and an electrolyzer, optimal tip speed control algorithms for low-power turbines, and low-cost electricity can provide the needed factors for successful realization of low-cost H_2 production. This project will coordinate with an ongoing NREL and Xcel Energy project, as well as develop cost and economic models for hydrogen production from any size renewable energy source.

The goal is to develop technologies that result in a net reduced cost of hydrogen (H2) production. To achieve this goal the following objectives must be accomplished:

1. Review and coordinate with the XCEL Energy Wind2H2 Demonstration Project.
2. Develop a H_2 cost model from small renewable energy sources on a residential scale (<10 kW turbines) using HOMER® (Hybrid Optimization Model for Electric Renewables).
3. Develop a cost model for the hydrogen from wind sources at all power levels.
4. Demonstrate a unique and new working system composed of a small wind turbine, power electronics converter and electrolyzer that optimizes wind tip speed under high dynamic wind speeds.
5. Utilize data from Cooper Nuclear Station on electrolyzer operation and maintenance costs to help facilitate extrapolation to all power scales.

Completion of this project is seen as a path by which the Nebraska Public Power District can utilize their renewable sources for providing H_2 fuel in a timely and cost-effective manner. It is expected that this project will coordinate technologies appropriate to NREL's wind/irrigation and wind/rural schools programs.

Category 3: Architecture; architectural engineering

10. Smart Building Energy Systems Monitoring, Controls and Diagnostics Using a Wireless Sensor Network for Energy Efficiency and Conservation

Principle Investigator: Haorong Li, Architectural Engineering - Omaha

http://www.nuengr.unl.edu/ENonline/Fall05/fc10.shtml

The trend of building functionality is to provide a personalized, comfortable and roductive indoor environment with low energy consumption and environmental impacts. However, the status quo of the building industry is non-personalizable with low energy efficiency and high operation and maintenance expenditure (about 15%~50% of the energy can be saved) because 1) the huge rewiring cost is a tremendous barrier for advanced technologies to be applied to old non-direct digital control based buildings; 2) limited useful information makes current buildings rely on costly manual continuous commissioning to recover the designed energy efficiency and functionality, and makes current buildings non-scalable/non-expandable to new control algorithms for improving energy efficiency; 3) the lack of flexibility makes the current building unable to provide personalized environment, 4) the current use of wireless technologies in building automation is mainly focusing on providing equivalent functionalities as their wired counterparts, which are not cost effective, energy efficient, and reliable.

The wireless sensor network (WSN) is an emerging cutting-edge technology which has a potential to enable a revolution in building monitoring, controls and diagnostics to overcome the above barriers and deficiencies due to its unique merits in cost effectiveness, energy-efficiency, fault tolerance, and capability of multi-dimensional information collection. We propose to explore the full potential of the synergy between the WSN technology and building monitoring, controls and diagnostics to enhance building energy efficiency and conservation. 1) to build a test bed of WSN-based building monitoring, controls and diagnostics systems to develop, implement, and deploy innovative methods for building energy systems and 2) through the test bed to demonstrate improved building energy efficiency and conservation, system cost-effectiveness, fault tolerance and reliability, flexibility in terms of building space reconfiguration and personalized environment, and scalability/expandability in terms of adding/adopting new technologies.

Category 4: Agriculture, agronomy, animal science, agriculture meteorology

11. Exploiting the Synergy between Ethanol and Distillers Grains

Principle Investigator: Galen Erickson, Animal Science

http://www.animalscience.unl.edu/faculty.cgi?facultyID=1039463183&who=Faculty

The University of Nebraska has been considered a leader in researching grain milling byproducts used by beef cattle. The beef cattle industry is the largest segment of agriculture in Nebraska, and use of byproducts is critical for competitiveness of Nebraska agriculture. This research area is rapidly changing as the ethanol industry continues to blossom in Nebraska. We must maintain the competitive advantages that ethanol plants, grain producers, and cattle operators currently experience. Despite all of the research focus in the past on byproducts, more is needed. Four specific areas of this project focus on: 1) performance of cattle fed modified wet distillers grains and evaluation of economics of use of modified wet distillers grains, 2) evaluation of diets that contain only byproducts compared to traditional grain based feeding programs, 3) management of sulfur in diets containing distillers grains, and 4) metabolism of distillers grains in combination with other ingredients (i.e., different corn types and roughage types) by feedlot cattle. The key for Nebraska is use of wet byproducts because our feedlots are very near the ethanol plants. No other state has this synergy of cattle, corn, and ethanol. The focus of this project is to address multiple questions remaining on how best to utilize byproducts, and how to maximize use in the future to maintain our clear advantage.

The goal of this project is to improve the use of feed byproducts produced from ethanol production, increase the use, and evaluate the economics for Nebraska agricultural producers. Specific objectives will address current limitations to more widespread use. This project focuses on a few different areas that are necessary to maintain our competitive advantage and synergy between corn, ethanol, and cattle in Nebraska. These objectives are: 1) to evaluate performance of cattle fed modified wet distillers grains and evaluation of economics of use of modified wet distillers grains, 2) determine if feedlot cattle can be fed diets that contain only byproducts and compare performance to traditional grain based feeding programs, 3) determine methods to decrease sulfur toxicity in diets containing distillers grains, and 4) metabolism of distillers grains in combination with other ingredients (i.e., different corn types and roughage types) by feedlot cattle.

12. Coupling Field Demonstrations and Simulation Model to Increase Energy and Crop Water Use Efficiency for Corn Production

Principle Investigator: Suat Irmak, Biological Systems Engineering

http://bse.unl.edu/about/Faculty/Irmak,%20Suat.htm

Energy costs coupled with limitations in water availability are threatening the sustainability of irrigation in the state. Energy cost for irrigation rose almost 100% for typical Nebraska irrigators from the spring of 2003 to the summer of 2006 and predictions are that it will rise at least another third in 2007. The rising cost of fuel and the limited availability of water supply make producing maximum crop yield with minimal input imperative.

Nebraska growers need scientifically-based and practical management strategies that can aid them in their decision making process to enhance crop water use efficiency and reduce energy use to achieve maximum profitability. Growers are looking for answers on how to make a maximum use of limited irrigation water and how to manage irrigation water to reduce pumping cost.

Crop simulation models with the capability of "real-time" assessment of crop and soil water status and yield prediction based on historical climate data represent a powerful new tool to help improve irrigation decisions and increase water-use efficiency – especially for situations where the amount of available water supply is less than the full requirement for maximum crop yield. Our proposal will validate and demonstrate a decision-support tool for real-time irrigation scheduling when irrigation water supply is limited in a series of on-farm demonstrations over a three-year period, and release the new tool as a software program for use by crop producers, crop consultants, and industry professionals. This tool will be used to assess energy requirement for different irrigation regimes to aid growers, state and federal agencies to make better-informed management decisions.

13. Dried Distillers Grains as a Source of Supplemental Energy and Protein for Developing Replacement Heifers

Principle Investigator: Rick N. Funston, West Central Research and Extension Center

http://www.westcentral.unl.edu/staffdir/Rick_Funston

Ethanol production is an important industry in Nebraska, in which distillers grains are co-produced during the fermentation process. Demand for distillers grains grows synchronously with increased production of ethanol. The goal of this research is to evaluate the value of distillers grains as a source of supplemental energy and protein in replacement heifer development diets, potentially enhancing the profitability of ethanol production from corn. Distillers grains have approximately 120% the energy of corn in forage diets and contain relatively high levels of crude protein, making them an economically feasible energy source in replacement heifer diets. Some Nebraska producers are feeding distillers grains to replacement heifers, but have concerns regarding the lack of research related to possible effects of feeding dried distillers grains in developing heifer diets. Therefore, this research is needed to address producer-driven concerns and is both warranted and necessary for adoption of distillers grains as a major component of heifer development rations. Completion of this research is necessary to determine if distillers grains affects any specific reproductive responses such as age at puberty, synchronization rate, AI conception rate, or pregnancy rate, and to justify the use of distillers grains as the primary source of energy and protein for replacement heifer development. Nebraska producers maintain an inventory of approximately 2 million beef cows. At a modest 15% replacement rate, this represents almost 300,000 replacement heifers developed annually, which could equate to an additional demand of 210,000 tons of distillers grains.

The goal of this research project is to evaluate the value of distillers grains as a source of supplemental energy and protein in replacement heifer development diets, potentially enhancing the profitability of ethanol production from corn. Objectives in reaching this goal are as follows: (1) Determine whether supplementation of prepubertal heifers with excess undegradable intake protein (UIP) from distillers grains affects age or weight at puberty; (2) Evaluate the response to estrous synchronization, artificial insemination conception rate, and pregnancy rate of heifers fed distillers grains during development; and (3) Communicate the value of distillers grains in heifer development systems to beef producers in Nebraska.

Category 5: Economics, policy feasibility studies

14. An Economic Analysis of Enterprise Options for the Bio-based Economy Initiative in Central and North Central Nebraska

Principle Investigator: Alan E. Baquet, Agricultural Economic

http://cari.unl.edu/a-baquet.shtml

A fifteen county region in central and north central Nebraska has been designated as a bio-based business development friendly region. The significant level of biomass feedstocks in this region could support a variety of bio-based energy enterprises, however, little is known at this time about which enterprises are potentially feasible and compatible with the resource base.

Through collaborations with several public and private entities in the region, alternative enterprises will be identified. A detailed analysis of the economic feasibility, environmental sustainability and impacts on rural communities will be conducted for each alternative. The results of the investigations conducted will provide information for decision makers about the alternative enterprises and their compatibility with the resources in central and north central Nebraska. The methodologies developed will serve as prototypes for other geographic regions.