Section C: PROJECT DESCRIPTION

Overview

During the last 20 years, there has been a growing realization that sustainable development must receive a higher priority in the years ahead. There is a particular need for scientists and engineers with expertise in sustainability who can develop innovative solutions to the problem of dwindling natural resources. This proposal requests funds for 9 undergraduate students each year to participate in a 10 week summer research program that will allow them to conduct research on a sustainable energy, work in a multidisciplinary research environment, and learn more about current developments related to sustainability. The title of this REU will be "Earth, Wind, and Fire: Sustainable Energy for the 21st Century". This title reflects the different types of renewable energy the students will be learning about (earth = biofuels, wind = wind energy, fire=solar energy) and should be instantly recognizable and interesting to undergraduate students. The goal of the program is to provide a rich research experience focused on the personal and professional development of the participants. Specific learning objectives of this project include:

1. To develop and apply knowledge and skills in the areas of mathematics, science, engineering, and research methods
2. To develop an understanding of sustainability as an applied multidisciplinary field encompassing economics, science, and technology, and the social, political, and ethical issues facing contemporary societies
3. To develop a recognition of the need for, and an ability to engage in life-long learning by increasing the capacity for self directed learning and original investigation

We also hope to enhance recruitment of students, particularly students from underrepresented minorities, into graduate studies in science and engineering.

The core of the program will be interdisciplinary research projects related to sustainable energy. These projects will involve faculty from chemical engineering, electrical and computer engineering, mechanical engineering, biological and agricultural engineering, grain science, physics, pathobiology, biochemistry, and chemistry. In these projects, students will acquire research skills and become aware of the technical skills required for addressing challenges in sustainable energy. To enhance the interdisciplinary nature of the research, weekly research meetings will be held with all REU students and faculty from several of the different disciplines. At these meetings, students will briefly present their research results. At the end of the REU experience, a symposium will be held where all students orally present their research.

In addition to their research, students will participate in weekly seminars on sustainability and professional development. The sustainability seminars will present such topics as triple bottom line, climate change, sustainable energy, carbon taxes and carbon trading, wind energy, solar energy, biofuels, sustainable transportation systems, energy efficiency and conservation, water, land, sustainable indoor environments, population, and sustainable food systems. These seminars will be part of a formal course, ChE 670 Sustainability Seminar, for which the students will receive one hour of

academic credit. The professional development seminars will include topics such as laboratory safety, laboratory research notebooks, multidisciplinary teamwork, writing a scientific paper, patents and patent applications, technical presentations, poster presentations, graduate education, and career paths. Students will also be asked to keep a journal in which they reflect on what they learn in the seminars, and how their research is proceeding. These experiences will complement the technical expertise the students get from their research projects by providing them a broader perspective on sustainability and their possible role in development of sustainable systems.

A final key component of this project will be the inclusion of a team project on sustainability. Students will be asked to identify a project they would like to work on related to sustainability early in the REU experience. This project could be an analysis of the potential for sustainable energy in Kansas, preparation of an article on sustainable energy that could be submitted to a journal, or writing an editorial on sustainable energy for publication in a newspaper. Students will then work on this project at designated work times through the 10-week experience, and will complete and present their work in the last week of the REU program. This team project will allow students to see the broader implications of their research, and to see how they can positively impact society through research.

Social activities will be planned to build community among the REU students and faculty mentors. These will include weekly "brown bag" lunches on campus, field trips to unique sites at and near K-State (local nanotechnology company, wind farm), and evening activities such as a hike on a nearby prairie.

Evaluation of the REU will be conducted by a team of evaluation experts both during and after the REU experience. Journal entries will be evaluated in terms of student learning and perspective transformation. In addition, a post-experience survey containing both qualitative and quantitative questions will be sent to REU participants 6-9 months after the experience. Finally, an existing program at K-State (CORES or the Collaborative for Outreach, Recruitment, and Engagement in STEM Program) will be utilized to track REU participants to determine whether the objective of encouraging participation in graduate studies has been met.

Students will primarily be recruited by contacting nearby colleges and universities in Kansas, all Big 12 universities, and all universities with engineering colleges within about 600 miles. There will be special efforts to recruit students from Haskell Indian Nations University (located in near-by Lawrence, KS), other Native American universities, and historically black universities.

The operation of the REU will be overseen by the co-PIs, Keith Hohn and Larry Erickson. Responsibilities for other aspects of the program will be split among members of a leadership team. Keith Hohn and Larry Erickson will be responsible for the weekly research meetings and for organizing the social events. Jennifer Anthony, Ruth Miller, and John Pickrell will administrate the weekly professional development meetings. The weekly sustainability seminars will be run by Ben Champion, Larry Erickson, and Oral Saulters.

Nature of Student Activities

Students involved in the "Earth, Wind, and Fire: Sustainable Energy for the 21st Century" REU will be immersed in an experience that allows them to develop valuable technical skills, learn about sustainability and the tools needed to provide for sustainable systems, improve their personal skills, and develop a community with the faculty and student participants in the REU. Table 1 summarizes the activities that will help the students achieve technical competence, develop their skills, and form a community with each other and the faculty mentors. Table 2 shows the anticipated schedule of these activities.

Table 1. REU Activities

Development of Technical Expertise	**Personal Development**	**Community Development**
• Multi-disciplinary research project on sustainable energy • Weekly research meetings • Research Symposium • Sustainability project • Sustainability seminar	• Weekly professional development seminars • Journaling	• Brown bag lunches • Field trips • Evening Activities

Table 2. Weekly Schedule for "Earth, Wind, and Fire: Sustainable Energy in the 21st Century" REU

Day	Time	Weeks 1,2,4,5,7,9	Week 3,6,8	Week 10
Monday	Morning	Research	Research	Research
	Afternoon	Research	Research	Research
Tuesday	Morning	Research	Research	Research
	Afternoon	Research	Research	Research
Wednesday	Morning	Research	Field Trip	Sustainability Project
	Afternoon	Research	Sustainability Project	Sustainability Project
Thursday	Morning	Research	Research	Sustainability Project
	Afternoon	Research	Research	Sustainability Project
Friday	Morning	Sustainability Seminar, Personal Development, Research Meeting	Sustainability Seminar, Personal Development, Research Meeting	Sustainability Research Symposium
	Afternoon	Brown Bag Lunch, Research	Brown Bag Lunch, Research	Wrap-Up

Development of Technical Expertise

The heart of the proposed REU is to engage undergraduate students in multi-disciplinary research projects related to sustainable energy. Through these projects, students will gain a detailed knowledge of one aspect of sustainability, and will acquire some of the skills necessary to conduct meaningful research in sustainable energy. Faculty at K-State conduct research in a wide variety of topics related to sustainable energy. Teams of researchers will be assembled to mentor the undergraduate students in research in a particular area of sustainable energy. Listed below are the anticipated research projects and the faculty teams for those projects.

Heterogeneous Catalysts for Hydrolysis of Lignocellulosic Biomass (Hohn, Wang, Anthony)

Cellulosic ethanol is thought to have significant potential to reduce United States' dependence on imported oil, with one recent estimate suggesting that 30% of the current petroleum consumption could be replaced by cellulosic ethanol from perennial energy crops, crop residue, and forestry biomass(Perlack, 2005). The challenge in producing ethanol from cellulose is the difficulty in breaking down cellulosic matter to sugars. Cellulosic materials are a complex mixture of cellulose, hemicellulose, and lignin. In their original form, the cellulose of these materials is not readily available for hydrolysis, so pretreatment (both physical and chemical) is usually required. In this research project, solid acid catalysts will be studied for use in cellulose hydrolysis. These catalysts will be synthesized with a magnetic (magnetite) core to allow easy separation using a strong magnet. Acidity will be provided by growing a layer of mesoporous silica or alumina-silica on top of the magnetite core(Mbaraka, 2006). Solid acid catalysts will provide two significant advantages over other hydrolysis methods (enzymes and mineral acids): they can easily be recycled and reused and the acidity can be tailored by changing the composition of the mesoporous coating.

Wind Energy (Miller, Lewis, Scoglio)

The Kansas Wind Applications Center at K-State has a primary purpose of educating wind engineers. Towards that end, it engages students in setting up anemometer towers, downloading and processing the anemometer data and determining the wind resource availability at a given site from those data. Both macro-and micro-site assessment, for placement of large wind farms and individual turbines respectively, rely on such data and related processing. The Center also models renewable energy sources, grid integration and energy storage.

REU students will conduct research in modeling and optimizing wind turbines, in modeling interconnected small energy sources, and in storage of renewable energy. In the wind turbine research, a generator driven by a DC motor will be used to model wind turbines. The torque applied by the DC motor will be changed to match real-time wind data obtained from anemometer instrumentation, and optimal control strategies for extracting maximal wind energy will be developed and tested. A computer model of

many interconnected small energy sources, including wind turbines and small-scale solar installations will be developed, and the power flows under various scenarios of available wind and solar energy will be modeled(Pompili, 2008; Anjali, 2005). In addition, scenarios will be run where solar and wind energy are combined with conventional (fossil-fuel) power plants to determine what would happen to power flows should the conventional power fail and to calculate how much fossil-fuel-generated power is necessary in a grid or microgrid to meet demand with an increasing percentage of total capacity being provided by renewable but intermittent sources. Energy storage research will examine the use of compressed air and water hydrolysis to hydrogen for subsequent conversion to ammonia as methods for storing excess energy from renewable sources.

REU students involved in this research will benefit from interaction with the Electrical Power Affiliates Program (EPAP) at K-State, which supports research in electrical power. REU students will be invited to take part in seminars and research meetings held by EPAP and will benefit from discussions with EPAP researchers (graduate and undergraduates students and faculty mentors) about power engineering.

Materials for Solar Power Generation (Higgins, Li, Bossmann, Klabunde)

Tremendous opportunities exist in the area of photovoltaic solar cells. While current Si-based devices can be highly efficient, the high cost of these cells limits their application. Research will be conducted to develop photovoltaic systems that incorporate nanostructures and organic molecules(Bossmann, 2005; Schild, 2002; Lahav, 2000). For example, vertical arrays of carbon nanotubes and semiconductor nanowires could have both high excitation efficiency and high electrical conductivity, making them useful components in photovoltaics(Ngo, 2006: Ng, 2003). Another research direction is to prepare organic thin film solar cells by self-assembly of a combination of small molecule organic semiconductors and semiconducting organic polymers with molecular-level control over film thickness, composition, organization, and orientation(Xie, 2005). REU students involved in this research will synthesize novel materials and characterize the chemical and physical properties of these materials.

Production of Chemicals and Fuels from Biomass (Rezac, Pfromm, Yuan, Hohn, Sun, Vadlani)

The production of chemicals and fuels from renewable biomass sources offers the potential to replace petroleum-based processes currently used. However, significant challenges remain in developing economical processes based on biomass. One challenge is finding active organisms and catalysts that can produce value-added products, such as succinic acid, 2, 5 – furan dicarboxylic acid, glucaric acid, glutamic acid, and amino acids. REU students will be involved in developing efficient microbial strains and fermentation processes for production of these important chemicals(Vadlani, 2008; Singh, 2008; Vadlani, 2007). They will also research silica-based enzymatic catalysts that offer the extraordinary selectivity of enzymes along with the stability and robustness of heterogeneous catalysts(Würges, 2005).

Challenges also exist in using thermochemical routes, where pyrolysis or gasification produces gases, liquids, or solids which are utilized for chemicals and energy

production. This route is advantageous because it is less sensitive to biomass type. Research will be conducted to optimize a hydrothermal pyrolysis system for bio-oil conversion, and to compare and understand the bio-oil yield and quality of various lignocellulosic biomass. In addition, a low-bulk density biomass gasification system will be optimized and tested for synthesis gas production. Additional research will be on highly efficient catalysts for bio-oil purification and synthesis gas conversion into liquid fuels, such as alcohols. REU students will operate the pyrolysis and gasification systems and characterize the products of those systems(Hu, 2008; Gan, 2008).

A final challenge for biomass-derived chemicals and fuels is purification of chemicals and fuels following the conversion of biomass. REU students will also be involved in research in the selective recovery of biofuels from fermentation broth using novel membrane processes(Singla, 2002; Wilks, 2002; Vetter, 2007).

Sustainable Energy on a University Campus (Champion, Erickson, Miller)

Knowledge of the scientific basis behind sustainable energy generation is not enough for successful implementation of sustainable energy systems. Consideration must be given to factors such as economics, availability of resources (wind, solar energy), and political and environmental implications. College campuses nationwide are taking a lead role in using renewable energy sources to meet their needs. For example, the University of Iowa is burning oat hulls in place of coal, generating about 10 million kW-hrs of green power annually for use on campus. K-State has created an Office on Sustainability, and appointed Ben Champion as the Sustainability Point Person on campus. This office will be evaluating potential actions for improved sustainability at K-State. An REU student will contribute to these efforts by evaluating the economic and technical feasibility of sustainability projects for campus. One example will be to evaluate the use of wind energy to supply some of the campus energy. For this project, REU students will acquire data on the wind resources on campus, evaluate wind turbine designs, and evaluate the economics of installing and maintaining wind turbines.

Small Renewable Energy Systems (Pahwa, Erickson, Miller)

A large portion of the world's population lives without or with intermittent electricity supply. In many cases, these people live in remote areas and thus providing them electricity through grid connection is not practical. The idea of small renewable energy resources to meet the basic energy needs in such situations is very attractive(CANREN, 2002). The small resources could be based on wind or solar. Several organizations are already promoting portable solar lanterns to meet the lighting needs of villagers. The current versions of the solar lamp are expensive and heavy. The local chapter of Engineers Without Borders (EWB) at Kansas State University is currently working on developing a cheaper and lighter version of the solar lantern. The proposed research will focus on investigating small renewable resources to meet the energy needs of people. REU students will test ideas on how to make lighter solar lanterns and evaluate the economics of these lanterns. Success of this research will have significant impact on the lives of a large population of the world. Since this approach does not depend on fossil fuels to meet the energy needs, it will have a significant impact

on the carbon footprint of the future. Success of this research also has potential to reduce dependence on existing fossil fuel resources and thus reduce emissions of greenhouse gases. There are energy needs in remote locations in all countries.

Anaerobic Digestion of Renewable Biomass (Erickson, Castro, Davis, Yuan)

The Group of Eight industrial nations have set a goal to reduce greenhouse gas emissions by 50% by 2050. In order to accomplish this goal, there is a need to reduce emissions associated with manure, wastewater, food wastes, leaves, wood wastes, and other renewable organic materials. There are significant opportunities in Kansas to reduce greenhouse gas emissions by producing methane and capturing and sequestering the carbon dioxide that is produced. Anaerobic digestion of mixtures from multiple sources will be investigated using both modeling and experimental work. The products to be added will be characterized with respect to their biochemical content and energy content based on known anaerobic degradation pathways and extent of oxidation using available electron concepts (Erickson, 1988). The concept of a community anaerobic digestion system to reduce carbon dioxide emissions will be investigated (Ahring, 2003a and b). The REU students will participate as a member of a multidisciplinary team that is working to advance applied research on anaerobic digestion with applications in Kansas and elsewhere.

Faculty mentors interested in working with an REU participant will be asked to submit a brief (two-page) application by February 1st. This application will detail the research problem to be addressed, the applicability of the research towards sustainable energy, the methods used to address that problem, the faculty members involved in the research and the resources available to the REU student for this project (availability of graduate student mentors and important equipment, money for supplies, etc.). Projects will be selected by the REU steering committee (Anthony, Erickson, Hohn, Champion, Miller) based on the intellectual merit of the proposed research, how well the research fits the sustainable energy theme of the REU program, and the extent to which the students will be involved in multidisciplinary research. The selected projects will be listed on the REU website and in information sent to prospective REU applicants. If there are more acceptable projects than REU students, student preference on projects will determine which projects ultimately receive an REU student. Table 3 lists the faculty members who will mentor students and their research interests.

Table 3. Research Mentors

Name	Department	Research Interests
Jennifer Anthony	Chem. Eng.	Green Chemistry, Mesoporous Materials
Ben Champion	Geography	Sustainability
Larry Erickson	Chem. Eng.	Biochemical Engineering, Environmental Remediation, Anaerobic Digestion
Steve Eckels	Mech. Eng.	Environmental Systems; Indoor Air Quality
Keith Hohn	Chem. Eng.	Catalysis, Biomass Conversion
Dan Higgins	Chemistry	Organic Photovoltaics, Spectroscopy
Kenneth Klabunde	Chemistry	Nanotechnology, Photocatalysis
Jun Li	Chemistry	Photovoltaics, Nanotechnology
Ruth Miller	Elect. Eng.	Wind and Solar energy
Caterina Scoglio	Elect. Eng.	Integration of Energy Systems
Anil Pahwa	Elect. Eng.	Small-Scale Renewable Energy Systems
Stefan Bossmann	Chemistry	Photovoltaics, Carbon Dioxide Reduction
Chris Sorensen	Physics	Aerosols and Nanotechnology
Mary Rezac	Chem. Eng.	Separations, Membranes, Sustainable Energy
Peter Pfromm	Chem. Eng.	Separations, Membranes
Donghai Wang	Bio. and Ag. Eng.	Fermentation, Lignocellulose hydrolysis
Wayne Yuan	Bio and Ag. Eng.	Biomass Conversion, Gasification
Sigifredo Castro	Advanced Manufacturing Institute	Anaerobic Digestion
Chris Lewis	Elect. Eng.	Networks and Systems Control
Lawrence Davis	Biochemistry	Plant Biochemistry
Susan Sun	Grain Science	Biomaterials
John Pickrell	Pathobiol.	Health Effects of Nanoparticles, Biofuels

In addition to the research projects, students will take part in weekly research meetings as a group. These meetings will be facilitated by the two co-PIs, Keith Hohn and Larry Erickson. At least one faculty member from each of the research projects will attend the meeting to provide a diverse perspective. At each research meeting, three REU students will report their research progress. These meetings will help develop the ability of the students to present their research results to a multidisciplinary audience and will advance the research effects by requiring each student to think about the work that is being done, including goals, plans, methods, and expected results.

Students will also attend a weekly meeting on sustainability, as part of a one-hour course, ChE 670 Sustainability Seminar. At this meeting, topics such as triple bottom line, climate change, sustainable energy, carbon taxes and carbon trading, wind energy, solar energy, biofuels, sustainable transportation systems, energy efficiency and conservation, water, land, sustainable indoor environments, population, and sustainable food systems will be discussed. Larry Erickson, Oral Saulters and Ben Champion will have primary responsible for the content of these seminars. Larry Erickson has offered

this seminar in two previous semesters during the academic year. Table 4 lists proposed contributors to the sustainability seminars and their expected contribution.

Table 4. Contributors to Sustainability Seminars

Name	**Department/ Organization**	**Contribution**
Larry Erickson	Chem. Eng.	Management and Leadership
Ben Champion	Geography	Dialog Facilitation and Leadership
Oral Saulters	Center for Hazardous Substance Research	Dialog Facilitation
Ruth Miller	Elect. Eng.	Wind and Solar Energy
Richard Nelson	Engineering Extension	Biomass Resources
Jennifer Anthony	Chem. Eng.	Carbon Sequestration and Carbon Markets
Bruce Snead	Engineering Extension	Energy Conservation and Energy Efficiency
Joe Aistrup or John Carlin	Political Science	Sustainable Energy and Policy Issues
Jeff Peterson	Agricultural Econ.	Triple Bottom Line
Steve Eckels	Mech. Eng.	Sustainable Indoor Environments.

At the conclusion of the summer program, students will give oral presentations at a research symposium to allow them to present their work in a friendly and supportive environment. All of the participants from all of the multidisciplinary research teams (faculty, graduate students, and others not in the REU program) will be invited to attend and participate in the event. There will also be a keynote speaker to enhance participation, publicity, and public attendance at the event. Each student will give a 15 minute presentation with an additional 5 minutes for questions and discussion.

Professional Development

Another critical component of the proposed REU program is a weekly seminar series designed to enhance the students' professional development. These seminars will include topics such as laboratory safety, laboratory research notebooks, multidisciplinary teamwork, writing a scientific paper, patents and patent applications, technical presentations, poster presentations, graduate education, and career paths. These topics are critical for students interested in a career in research, but aren't formally covered in undergraduate or graduate programs. As part of the professional development seminars, students will be asked to maintain a journal where they reflect on their REU experience. In the first week, REU participants will journal on their initial perspectives and attitudes toward sustainability, science and engineering, and research. Each week the students will submit written information on the theoretical and technical aspects of their research as

well as reflect on the learning experiences for the week and any perspective changes with respect to attitudes toward sustainability, science and engineering, and research. At the end of the summer, the participants will be asked to review their journal entries, and synthesize these materials into a paper describing how their perspectives, attitudes, and understanding of sustainability, science and engineering, and research have been impacted by their REU experience. The purpose of this part of the program is to develop the ability to reflect on the learning experiences and write effectively about them. Table 5 lists the faculty members who will contribute to the personal development exercises and their anticipated contribution to these activities.

Table 5. Contributors to Personal Development Seminars

Name	**Department/ Organization**	**Contribution**
Jennifer Anthony	Chem. Eng.	Research Notebooks
Ruth Miller	Elect. Eng.	Working with the Solar Car Team
John Pickrell	Toxicology	Risk Assessment and Risk Management
Wendy Griswold, Larry Erickson	Center for Hazardous Substance Research	Writing a Scientific Paper
Steve Galitzer	Public Safety	Laboratory Safety
Chris Sorensen, Steve Eckels, Larry Erickson	Physics, Mech. Eng., Chem. Eng.	Working in a Multidisciplinary Team
Marcia Molina	KSU Research Office	Patents and Intellectual Property
Kenneth Klabunde	Chemistry	Starting a Company
Mary Rezac	Chem. Eng.	Research Presentations
Lawrence Davis, Olga Koper, Larry Wagner	Biochemistry, Nanoscale Corp., Wind Erosion Laboratory, USDA	Research Careers
Ben Champion	Geography	Applying for National Fellowships
SUROP Program		Graduate Education and Applications

To further enhance the development of the REU participants into outstanding scholars, all participants will be strongly encouraged to present their work at a regional or national technical meeting in the academic year following their REU experience. To help make this possible, funds are included in this proposal that the students could request to cover their registration and travel expenses.

Community Development

An important part of the REU experience is for the students to feel a sense of community with the other REU participants and with the faculty mentors. This collegial

atmosphere is key towards creating a positive environment for student growth. It will also help in our efforts to promote research as an attractive career path for the students.

To promote a sense of community, a variety of activities will be planned. Informal "brown-bag" lunches will be held weekly, where REU participants and faculty mentors will have lunch together on campus. The lunches will not have an agenda; rather, they will encourage discussion of topics other than science and engineering.

Field trips will be held three times during the ten-week period of the REU program to sites on or near K-State. The first will be to the wind farm near Salina, Kansas and to the Land Institute (an NGO), which is also near Salina. The Land Institute conducts research on sustainable agriculture, with the goal of developing an agricultural system with the ecological stability of the prairie and a grain yield comparable to that from annual crops. A new effort, The Climate and Energy Project, was started by the Land Institute in 2007 because of the importance of climate and energy to agriculture.

The second field trip will be related to energy and will include a tour of the nuclear reactor at Kansas State University and several solar energy installations in Manhattan, Kansas. This field trip will include dialog on nuclear energy and its importance in developing sustainable energy.

The third trip will be related to innovative technologies and will include NanoScale Corporation, the Institute for Environmental Research, and the Advanced Manufacturing Institute, all in Manhattan, Kansas. NanoScale Corporation was started by Professor Kenneth Klabunde; the company conducts research and manufactures nanomaterials for a variety of applications. Steve Eckels, Director of the KSU Institute for Environmental Research, leads the effort to develop sustainable indoor environments. Anaerobic digestion research is one of the energy projects at the Advanced Manufacturing Institute.

These field trips relate to the REU topic of sustainability, but will also serve to promote the development of community among REU participants. A final series of evening social activities will be organized to provide evening activities to promote interaction of the REU participants. Ice cream socials, organized by the Summer Undergraduate Research Opportunity Program (SUROP) and the Center for Undergraduate Research Experiences (CURE), will be held twice during the ten-week period. One early evening hike to the Konza Prarie will also be organized.

The Research Environment

Kansas State University (K-State) is a land-grant university located in Manhattan, Kansas with a student population of ~21,000. As a land-grant university, K-State has strong programs in agriculture and engineering to support the major industries in Kansas (agriculture, aircraft manufacture, oil and gas production).

K-State has several existing programs related to sustainability. The Center for Sustainable Energy was recently formed to promote multidisciplinary research with faculty participation from several engineering disciplines and the College of Agriculture. This center was formed in recognition of the significant potential for Kansas in renewable energy production from wind energy or biofuels. Research interests include biofuels such as biodiesel, alcohols, methane from anaerobic digestion and production of algae for

use as biomass energy resource. Kansas State University together with the Consortium for Environmental Stewardship and Sustainability (CESAS) organized a Dialog on Sustainability, which was held at K-State on July 17, 2008. This was the third annual dialog. K-State has recently appointed Ben Champion to the position of director of sustainability. In this position, Ben will coordinate K-State's efforts on sustainability.

K-State has a history of strong support for REU programs, for example the NSF-funded REU programs in Grassland Ecology, Mathematics, and Physics. The Graduate School self-funds the Summer Undergraduate Research Opportunity Program (SUROP). These summer programs, as well as other academic year programs including our Developing Scholars and McNair Scholars program, comprise the *Consortium for Undergraduate Research Experiences (CURE).* The Consortium links the undergraduate research program coordinators to sustain a University-wide undergraduate research infrastructure that makes each of the individual programs more substantive, more valuable to the students, more focused on the preparation for graduate education, and more of a pipeline into high-caliber graduate programs. The Consortium members share best practices, resources such as workshops and assessment instruments, and endeavor to provide quality research and networking experiences for participating students. For example, during the summer, the Consortium hosts two ice cream socials for all undergraduate research students and fosters communication among the various programs. This has led to such interactions as students from the REUs taking part in SUROP-sponsored graduate school preparation programs and SUROP students being included in social and scientific sessions hosted by the REUs.

Kansas State University has an excellent research and educational environment for nurturing undergraduate students. K-State ranks seventh nationally among universities for Rhodes, Marshall, Truman, and Goldwater Scholars and first among public universities for Rhodes, Marshall, Truman, Goldwater, and Udall Scholars. Eleven K-State graduates have been Rhodes Scholars, and 12 have been Marshall Scholars.

The faculty involved in the proposed REU have had extensive experience in mentoring undergraduate researchers. The twelve senior investigators have mentored over 80 undergraduate students(many of whom are women or ethnic minority students), resulting in more than 30 presentations and more than 20 publications. Some of the undergraduates mentored have been the recipients of prestigious national scholarships, for example, Chris Baldwin, Cynthia Riemann, and Lisa Kitten (Marshall Scholars), Emily Voigt (Goldwater, NSF Graduate Fellowship, National Defense Science and Engineering Fellowship), and Jonathan King (Goldwater, NSF Graduate Fellowship)

The diversity of faculty associated with this proposal includes a good mix of men and women, faculty who have previously lived in Asia, Europe and South America, and scientists and engineers from different disciplines. There are four women among the twelve senior investigators. In addition, eight different academic disciplines are represented. This diversity will strengthen the REU program by presenting the students with different viewpoints on sustainability.

Kansas State University has excellent research facilities in the area of sustainable energy. All of the faculty listed in Table 1 as potential research mentors maintain active research programs in or related to sustainable energy. Some specific pieces of equipment that will be useful for the proposed research includes: x-ray photoelectron spectrometer,

infrared spectrometer, chemisorption apparatus, x-ray diffractometer, electron microscopes, chemical reactors, fermentors, gas,liquid, and ion chromatographs, membrane separation equipment, pyrolysis and gasification equipment.

Student Recruitment and Selection

Direct communication will be used to invite and encourage applications to the "Earth, Wind, and Fire: Sustainable Energy for the 21st Century" REU program. In addition, a web page will be created to advertise the REU program which will contain short descriptions of summer projects that are offered by K-State faculty participants. While the internet will reach out to all parts of the United States, the direct communication will focus on all four year colleges and universities in Kansas and the Kansas City metropolitan area, all Big 12 universities, and all universities with engineering programs within about 600 miles of Manhattan, Kansas. We will also directly contact professionals at other colleges and universities with whom we have ongoing professional relationships.

A number of approaches will be taken to enhance the diversity of the REU applicants. There will be special efforts to recruit students from Haskell Indian Nations University (located in near-by Lawrence, KS), other Native American universities, and historically black universities. We will also work with the Multicultural Engineering Program, the Women in Engineering and Science Program and the Student Undergraduate Research Opportunities Program (SUROP) to encourage applications that enhance diversity. Another K-State resource that will aid recruitment of students from underrepresented groups is the Collaborative for Outreach, Recruitment, and Engagement in STEM (CORES) Program. CORES is K-State funded program designed to provide databasing and tracking capabilities for participating K-12 and undergraduate outreach and education programs. CORES also facilitates connections with community colleges in Kansas and minority-serving institutions elsewhere. Both of these avenues will be valuable in helping to recruit students from underrepresented groups to the proposed REU site program. We have commitments to undertake joint recruiting of students with the SUROP and existing REU programs. K-State has had 160 students participate in summer undergraduate research experience programs in the last five years, of whom 70% are female and 41% are members of underrepresented minority groups.

The completed application will include 1. a completed application form, 2. an essay of up to two pages describing the student's general interest in sustainability, research interests, and professional goals, 3. an academic transcript, and 4. letters of recommendation from two individuals. The application form will include name, mailing address, phone, e-mail address, age, gender, race or ethnicity, citizenship, college major, previous project or research experience (if any), specific areas of summer project interest related to the listed summer projects, and expected graduation date. The completed application will be due on March 1. The completed applications will be reviewed and ranked by a selection committee that will include Anthony, Champion, Erickson, Hohn, and Miller. The selection criteria will include merit, diversity, academic major, and professional goals. Of the nine NSF REU students, we would have a goal of including at least 5 engineering majors and at least two majors from chemistry, physics or another field of science or mathematics who have an interest in engineering. We would also try to

include at least two individuals that enhance diversity. Consideration will also be given to the distribution of students among the faculty based on the listed research project interests of the students.

After receiving the applications on March 1, the completed applications will be reviewed and ranked during the next ten days. We would expect to extend offers to the top ranked students by March 15 with their acceptance being due 10 days after the date the offer is made. The students will receive a clear statement of the financial details of the program, dates for arrival and departure, and information on the details of the plan of activities for the summer. We would also alert highly ranked students that are not selected in the first round that they are still being considered as alternates, and that we will communicate with them again if we are able to make them an offer. As soon as we receive word from an applicant that has turned us down, we will make an offer to the next person on the list.

Project Evaluation and Reporting

Project evaluation will be conducted to improve the REU program and to investigate transformative learning. Methods for program evaluation and assessment of student learning will measure how well the learning objectives have been met. Evaluation methods will be interwoven with the activities of the REU experience, for example the journaling activity. This will allow collection of rich data without imposing an extra burden on the participants. Evaluation activities will be used throughout the project to continuously improve the program and to provide a summative evaluation upon project completion. Follow-up surveys, containing a qualitative and quantitative mix of questions, will be conducted 6-9 months following the completion of the summer REU. The purpose of this is to learn about the participants' subsequent activities and to gain their perspectives on the program and its impact on their lives and career plans.

Tracking of students following their participation in the REU will be facilitated by the database recently constructed by the Collaborative for Outreach, Recruitment, and Engagement in STEM (CORES) Program at K-State. CORES is a K-State funded program designed to provide database and tracking capabilities for participating K-12 and undergraduate outreach and education programs.

Recent research findings indicate the potential of a range of educational experiences related to engagement in real world issues related to sustainability and natural resources to be facilitative of perspective transformation (Lange, 2004; Sims, 2008). This indicates that transformative learning theory (Mezirow, 1990) is an appropriate guiding framework for evaluation of the REU program learning objectives. The data that is collected from the weekly written entries will be analyzed in terms of 1) the students' learning and 2) perspective transformation. The data collected from all sources will be coded and managed using QSR N6 software to create a case study database.

Data will be coded using frameworks from Mezirow (1990) and the results of previous research in the area of transformative learning and sustainability (Lange, 2004; Sims, 2008), transformative learning theory and youth (Goula, 2007) and sustainability education frameworks (Moore, 2005; The Cloud Institute for Sustainability Education,

2008). The use of Mezirow's framework will entail coding for statements related to the 10 stages of perspective transformation.

Emergent themes will also be included in the case study database. Data will be analyzed using a keyword phrase search derived from the aforementioned frameworks. The case study database will be utilized to conduct searches and to tabulate and manage search results.

Program Evaluation Team

Wendy Griswold, Jackie Spears, and Marie Steichen will perform the evaluations and prepare the evaluation reports. This team is conducting research on transformative learning and sustainability. Griswold and Steichen have been working together on evaluations for more than 5 years, and they have prior experience with evaluations for engineering and sustainability programs (Steichen et al., 2006; Bhandari et al., 2007). Marie Steichen has a Ph.D. from K-State, and she has been a program evaluator on local, state, national, and international projects for Kansas State University for the past 12 years. Jackie Spears directs the Center for Science Education at Kansas State University.

Relationship of Proposed REU Site to Evaluation Criteria

Intellectual Merit

REU students will be involved in cutting edge research on materials and processes for production of sustainable energy. By the interaction of researchers from many disciplines, the research produced by the REU students will be enhanced. Advancement in the knowledge base on sustainable energy will result from this research.

Broader Impacts

The proposed REU site will provide a rich research experience focused on the personal and professional development of the participants. Students will gain not only the technical abilities required to conduct research in sustainable energy, but will also become aware of the social and political issues associated with sustainable energy. By being involved in a team project on sustainable energy, students will learn to seek outside sources of information and will gain an increased capacity for self directed learning and original investigation. The REU site will also enhance the participation of students from underrepresented groups in research and in graduate school.