

Project Descriptions

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 Resource Assessment (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.

Renewable Energy and Smart Grid