E3 2010 Research Posters

The following pages include abstracts submitted by researchers prior to Nov. 17, 2010. This research is funded in part by the Initiative for Renewable Energy and the Environment, a signature program of the University of Minnesota's Institute on the Environment. Visit the E3 poster area for information on the project investigators, research outcomes and more.

1. Sustainable Forest Feedstock for Bioenergy Production in the Lake States: Enhancing Physical, Economic and Social Availability

Despite the potential for significant utilization in the production of bioenergy and biofuels, little is known of the economic, environmental and social availability of forest biomass or the cumulative effects of increased demand. Past studies have estimated total physical biomass available without taking into account the range of constraints imposed by transportation distances, harvest costs, environmental laws or site access. Supply estimates are further complicated by uncertainties about the willingness of private landowners to sell timber or thin forests for biomass. The result is a potential overestimation of supply that threatens the viability of new and existing businesses and the sustainability of the forest resource. Study results are presented on the long-term physical availability of forest biomass across northern Minnesota and Wisconsin to compare to measures of environmental, economic and social availability. Variations in management intensity are modeled to illustrate changes in volume under different sustainability thresholds and implications for increasing the use of biomass for bioenergy production in the Lake States.

2. A Biorefining Model for a High Corn Oil

Corn has been the largest ethanol feedstock in the United States, but it hasn't been considered an economic feedstock for biodiesel (as soybean has) due to its low oil content. Korea high oil corn (KHO) was found to have around 19% lipid content. It is believed that this corn breed could potentially be processed for both ethanol and biodiesel production. Among the most used corn milling methods, wet milling can achieve the cleanest germ separation. To prove the feasibility of laboratory wet milling, a degermination test, a starch separation test and fermentation were carried out for KHO, a control corn (A619) with common oil content and a hybrid of KHO (F4). The results were compared, and a processing model including four blocks was raised based on the results.

3. Effects of Exogenous Carbon Dioxide on Biomass, Lipid Production and Nutrient Removal of a Local Screened Mixotrophic Microalgae *Auxenochlorella Protothecoides* Cultivated In Centrate Wastewater

This project explores the potential of microalgae in industry and as a feedstock for production of renewable fuels such as biodiesel. Also considered are algae-based wastewater treatment, mixotrophic algae strain *Auxenochlorella protothecoides* in centrate wastewater, photoautotrophic growth on light and carbon dioxide and heterotrophic growth on dissolved organic carbon in centrate. The potential function of the addition of exogenous carbon dioxide in algae culture in centrate wastewater, inorganic carbon resource for algal photoautotrophy and carbon dioxide fixation for the relief of the greenhouse effect are also of interest.

4. Adding Value to Ethanol Production Byproduct (Distillers Grain) Through Production of Biochar and Bio-Oil

The goal of this project is to increase the value of distillers grain by sequestering carbon and producing additional renewable energy resources (bio-oil and syngas) through microwave-assisted pyrolysis. More specifically, we will have an optimized process for capturing additional bio-energy and at the same time producing a potential soil improvement agent from an existing byproduct. We will examine the potential increase in soil fertility and carbon storage of this produced biochar. The potential long-term outcomes of this research are the development and promotion of on-farm energy production using microwave-assisted pyrolysis and distillers grain as a feedstock, as well as improving the sustainability of corn production by returning carbon to the field.

5. Development of Macroporous Cerium Oxide–Based Materials for Solar Thermochemical Hydrogen Production

Water can be split into hydrogen (H_2) with a two-step thermochemical cycle that uses cerium oxide (CeO_2) as a catalyst. In the cycle, CeO_2 is reduced in a high-temperature step and then reoxidized in a lower temperature hydrolysis step that produces H_2. Introducing porosity into the structure can increase surface areas, boosting catalytic performance. To enhance the surface area of the catalyst, three-dimensionally ordered macroporous (3DOM) materials containing CeO_2 were synthesized through templating methods. These materials have high surface area and interconnected pores that allow for improved mass transport. However, at the temperatures needed for thermochemical cycling, the nanocrystalline 3DOM materials undergo extensive grain growth and loss of porosity. Finding ways to mitigate grain growth and maintain high surface area is critical for making an effective catalyst. Adding dopant cations to CeO_2 can significantly decrease grain growth and alter the redox properties of the material. In this work, we investigate morphological changes at high temperatures in 3DOM CeO_2 and a variety of 3DOM CeO_2-containing mixed oxides. Many of the mixed oxides have increased reducibility, so the performance of the 3DOM materials in simulated cycling conditions is tested.

6. Microwave-Assisted Pyrolysis of Microalgae for Biofuel Production

The aim of this study is to test the feasibility of bio-oil production from microalgae biomass through microwave-assisted pyrolysis under different microwave power settings. The pyrolysis of *Chlorella* sp. was carried out in a microwave oven with char as microwave reception enhancer. The results indicated that the maximum bio-oil yield of 28.6% was obtained under the microwave power of 750 W. The bio-oil properties were characterized with elemental, GC-MS, GPC, FTIR and thermogravimetric analysis. The algal bio-oil had a density of 0.98 kg/L, a viscosity of 0.06 Pa s and a higher heating value of 30.7 MJ/kg. GC-MS results showed that the bio-oil was mainly composed of aliphatic hydrocarbons, aromatic hydrocarbons, phenols, long chain fatty acids and nitrogenated compounds, among which aliphatic and aromatic hydrocarbons (22.18% of total GC-MS spectrum area) are highly desirable compounds that are the same as compounds found in crude oil, gasoline and diesel. Algal bio-oils had better physical and chemical properties than those derived from lignocellulosic materials. Results of this study indicate that rapidly growing algae is a promising source of feedstock for advanced renewable fuels production via microwave-assisted pyrolysis.

7. Mimicking Fungal Biomass Decomposition Using Biphasic Biocatalysis
Deconstructing plant biomass en route to biofuels remains inefficient. This is the primary hurdle toward fully developing second-generation biofuels from lignocellulosic biomass. In particular, chemical pretreatments used to "loosen" biomass tissues before processing with enzymes are nearly 50% of the cost and remain unintegrated with other bioprocessing steps. Surprisingly, many of the fungi responsible for decomposing lignocellulose in nature have evolved mechanisms that integrate this pretreatment step. This project is focused on characterizing how fungi couple two incompatible reactions (oxidative pretreatment + enzymatic hydrolysis of carbohydrates) using a model brown rot fungus *Postia placenta*. The approach is to inoculate wood with this fungus in standard ASTM microcosms and to microtome early-decayed sections in order to harness, and then recreate, the gradients needed to partition incompatible oxidative pretreatments from enzymatic hydrolysis of biomass. Specifically targeted characteristics are pH, porosity and lignin-cellulase adsorptivity to control spatial separation. These variables are theorized to control reaction partitioning in the natural *P. placenta* system, and the aim is to harness this information to artificially reproduce partitioned oxidative/enzymatic reactions using structured biocatalysis.

8. Lactic Acid Fermentation Using Dairy Manure as the Sole Carbon and Nitrogen Source
L-Lactic acid is one of the most important organic acids used in food, pharmaceutical and chemical industries. A major and unique contribution that lactic acid can make to a renewable environment is its use in the production of biodegradable plastics that can replace the fossil-fuel-based nonbiodegradable plastic materials widely used today, leading to the reduction of global consumption of diminishing petroleum resources. This project explores the novel idea of producing lactic acid from dairy manure, a vast renewable resource, via batch fermentation by microorganisms such as fungi, with emphasis on the feasibility and possibility of microbial use of the nutrients in the manure (carbon and nitrogen source) for lactic acid production. The specific objectives of this project are: 1) develop effective processes for dairy manure hydrolysis by fungi by determining the most effective microbial culture or flora and the optimal operating parameter values for hydrolysis, and 2) investigate the feasibility and techniques of converting the hydrolysates from dairy manure into lactic acid through fermentation without external nutrients, and optimize the fermentation conditions to enhance lactic acid production.

9. Rigid Polyurethane Foams From Soy-Based Polyols
Polyurethanes have wide applications, and rigid foam accounts for 23% of polyurethane products. There is a strong trend to use bio-based renewable resources as the raw materials feedstock in the polyurethane industry. It has been found that the observed environmental impact scores for soy-based polyol showed only about one quarter the level of those defined for the petro-based polyol. Some work has been done in developing natural oil-based polyurethanes. This research is focused on investigating soy-based polyurethane rigid (PUR) foam properties, studying the mechanism behind the property deficiencies and developing strategies to improve them. Research found that soy-based PUR foams have density, cell morphology, glass transition temperature, compressive strength and thermal conductivity comparable to those of petro-based PUR foams. However, soy-based PUR foams show faster thermal conductivity aging. Foam aging is largely due to air ingress, since air has much higher thermal conductivity than pentane. N_2 permeation through the polyurethane thin film is studied to understand this fast aging problem. Experiments show that the soy-based PUR film shows much higher N_2 and permeation than petro-based PUR film.

10. Sodium Sulfur Battery Energy Storage and Its Potential to Enable Further Integration of Wind
This project evaluates the ability of storage, specifically sodium sulfur batteries, to facilitate the integration of higher proportions of wind generation into the power system. One of the goals of this project is to identify the optimal ratio of storage to wind if storage is used to shift generation from off-peak to on-peak, to smooth the output of wind generators and to enable wind resources to stick to the dispatch instruction. Wind generation could be uncorrelated or negatively correlated with the demand, which makes it necessary to shift it to on-peak. The rapid variations in wind generators' outputs could be too fast for the power system to handle, and storage could be used to control the ramp rates. The limited predictability of wind generation tends to make wind undispatchable in the conventional sense; however, storage could be used to enable wind generators to stick to their forecasted/dispatched energy output. It is expected that higher penetration of wind would result in higher variance in energy prices. Storage could be used to capture the difference in prices and earn revenue through energy arbitrage. Formulating an optimal dispatch strategy toward this aim is another goal of this project.

11. Development of Torrefied Wood Microchips as an Energy-Efficient Biofuel for Pellet Stoves and Boilers
Conventional wood pellet biofuels require substantial energy to chip, dry, hammermill and pellet during the manufacturing process. Further, recent growth in the pellet industry has resulted in an increased use of roundwood logs instead of traditional wood residues, creating manufacturing challenges in the wood pelleting sector that often result in poor pellet quality and lengthy and complex new plant start-up times. This project employs a paradigm shift for how wood biofuel pellets are manufactured. Researchers are working to reduce the energy requirements and manufacturing challenges of wood pellets by developing torrefied wood microchips. The research team is seeking to bypass the conventional tree-to-pellet approach by using combined microchipping and torrefaction as a more energy-efficient means of producing a wood biofuel that could be used in conventional pellet-burning appliances or as a feedstock for manufacturing torrefied pellets. During the project, wood microchips will be produced, torrefied and characterized to determine their energy density and durability. Microchip feed rate, flowability, completeness of burn and ash generation characteristics will be assessed in conventional pellet-heating appliances. Successful completion of this project will provide a solid foundation for another new, sustainable, energy-efficient next-generation biofuel to enter the marketplace.

12. A Metathesis Polymerization Route to Light Harvesting Polymers
Polymer photovoltaics have been the focus of significant interdisciplinary research efforts because of their potential for flexible large-area devices made possible by low-cost solution processing techniques. Herein we describe our recent efforts in synthesizing low band gap polymers and their performance in solar cells. The material of interest is poly (2, 5-thienylene vinylene) (PTV), which we prepare using acyclic diene metathesis (ADMET) polymerization. The functional group tolerance of ADMET and its associated catalysts will allow for numerous chemical modifications aimed at tailoring properties intrinsic to organic photovoltaic devices. It is generally accepted that device performance improves as polymer molecular weight increases. To investigate this, a series of PTVs having different molecular weights were prepared and studied in OPVs. We also wish to investigate the impact of electron-withdrawing moieties on solar cell performance by preparing a series of PTVs with chemically modified scaffolds. The results of these two studies are discussed in greater detail.

13. Laterally Integrated PV Devices—Economic Analysis
A new hybrid solar cell design is being developed that retains the low cost of thin-film devices but adds an inexpensive holographic concentrator that will enable thin-film devices to work together to make efficient use of the entire solar spectrum. The design is scalable and, importantly, compatible with continuing advances in photovoltaic thin-film materials. In fact, a new architecture for solar cell photovoltaics with a new level of performance, manufacturability and cost effectiveness is being developed. To accomplish this, the program is addressing cell modeling, optical design, optical testing, device fabrication and manufacturing costs. The presentation focuses more on the manufacturing costs and sustainability analysis.

14. Energy-Efficient Inorganic-Bonded Wood Panels for Construction Applications
We have combined the unique properties of chemically bonded inorganic binders with wood feedstock to develop fire-, moisture-, decay- and mildew-resistant prototype composite panels for construction applications. The inorganic binders are magnesium based and require significantly less energy to produce than the traditional petroleum-based resins found in most wood-based construction panels. The manufacture of the composite panels requires no heat, and the wood feedstock does not need to be dried. Thus, the manufacturing process requires much less energy and releases minimal VOCs when compared to traditional wood-based panels. Further, the inorganic binders do not contain formaldehyde, unlike most traditional resins. We envision this product as an improved and energy-efficient replacement for plywood, particleboard and high- and medium-density fiberboard in several applications, including laminating platforms and substrates for laminate flooring and/or engineered wood flooring, laminating platforms for kitchen and bathroom countertops, and bottom panels for sink bases. We are gauging industry interest in these and other applications and are continuing with further development.

15. Solar Gasification of Biomass: Kinetics of Pyrolysis and Steam Gasification in Molten Salt
The use of concentrated solar energy for pyrolysis and gasification of biomass is an efficient means for production of hydrogen-rich synthesis gas. Using molten alkali-carbonate salts as a reaction and heat transfer medium offers enhanced stability and higher reaction rates to these solar processes. To establish the reaction kinetics, experiments were carried out in an electrically heated molten salt reactor. Cellulose or activated charcoal was pyrolyzed or gasified with steam from 1124 K to 1235 K with and without salt. Arrhenius rate expressions are derived from the data supported by a numerical model of heat and mass transfer. The average rate of the reactions in molten salt, as measured by their reactivity index, is increased by 70% for pyrolysis and by one order of magnitude for steam gasification.

16. Solar Hydrogen: Zinc Nanoparticle Hydrolysis
This poster features work on the technical, economic and political viability of one intriguing approach for the efficient harvest and storage of solar energy: the high temperature zinc/zinc-oxide (Zn/ZnO) thermochemical water-splitting cycle. In this cycle, the feedstock is water and the heat source is concentrated sunlight. Pure hydrogen is produced without greenhouse gas emissions. Solar energy is effectively stored in the form of a fuel that, if desired, can be used at night, on cloudy days or in locations with limited available sunlight. The first step of the Zn/ZnO cycle is the dissociation of ZnO at approximately 2000 K. In the second, step, Zn is reacted with steam to produce ZnO and hydrogen. This hydrolysis step can be carried out whether or not the sun is shining. Ideally, the product ZnO can be completely recycled back to the first step, so the net effect is the splitting of water. Our research addresses the two main barriers to implementation remaining in this technology: incomplete hydrolysis and recovery of the ZnO in the second step, and the high initial cost of the technology.

17. Is Planting Forests Bad for the Climate?
Planting forests is one of few readily available and proven approaches to mitigating climate change through sequestering atmospheric carbon dioxide (CO_2). Avoiding a doubling in the concentration of atmospheric CO_2 from preindustrial values by mid-century will require a multitude of technologies and approaches—carbon sequestration through forest planting being one of the more practical ones. However, there is considerable uncertainty over whether afforestation/reforestation will actually do more harm than good. Planting a forest may decrease the surface reflectivity, resulting in greater net radiation being absorbed at the surface and thus surface warming. In some cases this warming can more than offset the climate benefit derived from carbon sequestration. Using a dynamic global vegetation model, the competing effects of fraction cover of forest, stand age and local climate on the total benefit to the climate system is evaluated. Model results indicate that regionally there are large variations in the climate benefit of forest placement. This study offers new insight on the feasibility of large-scale forest planting as a climate mitigation strategy.

18. Microwave-Based Biofuels and Biochemical Production From Non-Food Biomass
Challenges related to the nature of current lignocellulosic biomass production include distributed and seasonal production and low energy density with storage problems. Transporting bulky biomass from scattering production sites to a central processing facility has been a key barrier to large scale biomass utilization. Research suggests that biomass industry development should include smaller-

scale facilities to be economically viable: Solid biomass conversion to liquid biofuels or chemicals is a promising process to overcome logistic problems associated with the distances between locations where biomass is available and sites where fuel or chemicals are needed. Distributed conversion makes transportation, storage and further processing much easier and more economical. Thermal decomposition (pyrolysis) is a well-known process to produce bio-liquid (also called bio-oil, biocrude, pyrolysis liquid etc.) under relative mild conditions (atmospheric pressure and 450□ ~ 550□ in absence of oxygen), but the quality of the produced oil is far too poor for direct use as transportation fuels or even for upgrading in existing oil refineries. Solution 1: Microwave-Assisted Pyrolysis (MAP). Pyrolysis can take place rapidly in large-sized biomass materials such as woody biomass or cornstalks, thanks to the nature of fast internal heating by microwave energy.

19. Heat Transfer in Liquid Piston Isothermal Air Compressor/Expander
An "open accumulator" high-pressure compressed air approach has been proposed for storing excess wind energy locally. This approach does not require special geological sites or additional fossil fuel as in the conventional compressed air storage (CAES) approach. It relies on a combined hydraulics and pneumatic approach to attain both high energy density and power density. A critical element in the approach is an isothermal high pressure air compressor/expander. In this regard, research is underway to develop a liquid piston-based compressor/expander with improved heat transfer and sealing properties.

20. Roll Press Compaction of Corn Stover and Perennial Grasses
In a previous study, we developed a "field to facility" biomass supply logistics system. The system included collection and transport by round bales to local storage sites within 3.2 km (2 miles) of the field during harvest followed by processing at local storage sites throughout the year using mobile units that converted bales to bulk material by tub-grinding and roll-press compacting to 240 kg/m3 (15 lb/ft3) to achieve 22.7 t (25 ton) loads for truck delivery to an end user within a 48-km (30-mile) radius. The objective of the current study was to investigate the roll press compaction of corn stover and native perennial grasses. A 60-HP pilot-scale roll press compaction machine (Bepex International LLC, Minneapolis, Minn.) was used to compress corn stover and native perennial grasses ground in the Mighty Giant tub-grinder with three different screens [25.4, 76.2, and 127.0 mm (1.0, 3.0, and 5.0 in.)]. The bulk density of compacted materials ranged from 262.7 to 365.2 kg/m3 (16.4 to 22.8 lb/ft3) for the roll compaction forces of 0.21 to 0.53 MN (24 to 60 ton). The specific energy consumption for the operation of rolls and screw feeder ranged from 1.0% to 1.3% of energy in the biomass material.

21. Clean Tech Clusters
Clean tech—the production of electricity and fuels with reduced environmental impact—saw a mini-investment boom in the first decade of the 21st century. This study investigates the degree to which the strategies of clean tech investors varied over time in response to learning from investment successes and failures and from changes in public policy. The literature on path dependence predicts, all else equal, that initial patterns persist into the future. The past character of the investments will continue into the future without much alteration. Our model suggests this pattern can be broken based on the feedback investors receive from successful or unsuccessful rounds of venture capital funding and from the changes in the global economy, energy prices and clean-tech polices of global governments. Thus, there is another perspective that should be applied to the strategic choices that investors in this domain make, that is, learning theory. Its predictions would be that adjustments in strategic choices will take place based on factors included in our model.

22. *Shewanella* as an Ideal Platform for Producing Hydrocarbon Biofuels
Hydrocarbon biofuels offer the opportunity to produce high-energy fuels from renewable resources that are compatible with the current fuel infrastructure. We have shown that native *Shewanella* species produce hydrocarbon biofuels and can be engineered to produce higher levels of hydrocarbons. *Shewanella oneidensis* MR-1 was used as a model system to examine the genes involved in hydrocarbon biosynthesis as well as the biological function of the proteins they encode. A cluster of four genes, oleABCD, was identified to be involved in olefin biosynthesis. Additionally, a strain deleted in the native oleABCD genes and containing heterologous oleA from *Stenotrophomonas maltophilia* R551-3 was found to produce only ketones. A sixfold increase in ketone production has been obtained by optimization of the vector backbone and promoter of this modified strain. Furthermore, in vitro studies using Ole recombinant proteins expressed in *E. coli* proved that fatty acyl groups are the precursors of the head-to-head hydrocarbon biosynthesis mechanism. Attempts to increase fatty acid precursors through genomic manipulation are ongoing as well as the optimization of a fluorescence based high-throughput assay to screen for increased ketone production. The long-chain ketone feedstock generated by this approach can be readily processed to produce diesel fuel by cracking and hydroisomerization.

23. Biobased Pressure-Sensitive Adhesives
Pressure-sensitive adhesive (PSA) products have become ubiquitous in our homes and offices through address labels, stamps, sticky notes and tapes. The majority of these PSAs are based on petroleum-derived acrylates. In 2006, more than 300 million dry pounds of acrylic adhesive were sold in the United States. Incorporation of biomass-derived resources as a substitute for acrylates will make a significant contribution to the development of sustainable products. We developed PSAs with high biomass content using biomass-based macromonomers, which can copolymerize with standard adhesive acrylates and replace 40-60% of petroleum-based raw materials. The work described here is an example of a novel yet pragmatic approach to developing sustainable PSA formulations by simple modifications of successful commercial products while maintaining performance.

24. Hydrostatic Transmission for Wind Power Generation
The University of Minnesota is performing research on the application of continuously variable hydrostatic transmissions for wind turbines. By replacing the gearbox of traditional wind turbines with a continuously variable hydrostatic transmission (HST), the rotor speed could be controlled independent of the generator speed. This would allow the use of more conventional synchronous generators instead of higher cost variable speed permanent magnet generators and eliminate the need for power electronics. The

gearbox of traditional wind turbines is one of the primary sources of premature failure and maintenance. HSTs have been the dominant choice for propulsion in agricultural, construction, forestry and mining vehicles for more than half a century. Thus, replacing the gearbox in a wind turbine with an HST should improve the reliability of the machine. The IREE seed funding will be used by the University of Minnesota to begin the process of building a lab scale (50 kW) test stand to perform research on applying HSTs to wind turbines. The research will initially focus on determining the best drive train hardware configuration as well as on optimizing the wind turbine's control algorithm.

25. Using Light to Stimulate CO_2 Sequestration in an Organic Carbon-Rich Wastewater by Mixotrophic Green Microalgae UMN280

A number of benefits can be obtained by using wastewater-based mixotrophic cultivation for algal biomass production. First, costs associated with nutrients and water supplies for algae growth will be greatly reduced or eliminated. Second, if algae are grown in wastewater, they will help remove nutrients, particularly phosphorus and nitrogen, and capture carbon dioxide (CO_2) and other potential greenhouse gases in air or flue gas. Algae are also able to use large quantities of organic carbon from the wastewater streams, which would otherwise be emitted into the atmosphere. Third, it was reported that mixotrophic growth of algae is approximately the sum of autotrophic and heterotrophic growth, which represents the fastest way of growing algal biomass. Considering all above advantages, it was believed that the wastewater-based algae biofuel process is the sustainable option among existing processes. The objectives of this research are to identify the role of light and exogenous CO_2 in the mixotrophic cultivation system, to determine if higher light intensity could increase CO_2 utilization, and to provide suggestions for parameter selection for future pilot-scale production system operation.

26. Cultivating *Chlorella* Sp. in a Pilot Scale Photobioreactor Using Centrate for Microalgae Biomass Production and Wastewater Nutrients Removal

Oil-producing algae are a promising biofuel feedstock with the potential to meet the world's ambitious goal to displace fossil fuels with biofuels without displacing traditional food crops. However compared to traditional biofuel crops, mass algal production systems have higher environmental impact associated with water usage, nutrients inputs and energy consumption. Wastewater and flue gas should be used to mitigate the environmental burdens. On the other hand, with increasingly stringent regulations and limits on wastewater discharge and gaseous emissions, modifications of current conventional processes must be made to meet these new limits. Growing algae in wastewater streams can offset additional costs for nutrient and water supplies for algal growth, help remove nutrients from wastewater streams, and assimilate large quantities of organic carbon for biofuel production. By far, coupling algae production with wastewater treatment seems the most practical way for algae-based biofuel production to succeed. The objective of this study is to determine harvesting rates and CO_2 effects on biomass productivity and nutrients removal from wastewater and obtain the best operational scenario.

27. Solar Fuels

Solar fuels harness the sun's energy and store it in chemical bonds. These fuels are achieved by concentrating solar energy and using the resulting high-temperature, high-quality radiant source as process heat to drive chemical reactions whose products are the desired fuels. In order to test at a laboratory scale the reactors used to effect these chemical reactions, the Mechanical Engineering Department at the University of Minnesota has designed and is currently building a high-flux solar simulator. The simulator will enable the researchers in the solar laboratory to determine optimal designs and operating conditions of these reactors in a controlled environment, allowing for a high degree of repeatability in experiments.

28. The Genomic Sequence of the White-Rot Fungus *Trimetes Cingulata*

The presence of lignin in secondary cell walls makes wood very resistant to decay. White-rot fungi, such as *Trametes cingulata* and *Phanerochaete chrysosporium,* are typically found on hardwoods and degrade the three major cell wall components: lignin and the carbohydrates cellulose and hemicellulose. These fungi leave behind modified wood that appears bleached and is soft and spongy due to the loss of lignin and significant amounts of carbohydrate. On the other hand, *Postia placenta* is a brown-rot fungus, which typically degrades softwoods, consuming the carbohydrates and leaving behind a brown and crumbly substrate that consists mostly of modified lignin. To address the mechanism of lignin degradation, we have sequenced the genome and transcriptome of *Trametes cingulata* and compared its predicted secretome with those of the related fungi *P. chrysosporium* and *P. placenta.*

29. Ss-Tmg Design Performance

The Thermo-Mechanical Generator was invented in 1967 and is an ingeniously simple and elegant heat engine operating on a Stirling thermodynamic cycle that can yield cogenerated electrical and thermal energy from moderately hot heat sources (200–500°C). A new version of this heat engine has been invented that is capable of operating off concentrated solar energy provided by inexpensive, acrylic Fresnel lenses. A key innovation in the technology is the use of a digital thermodynamic Smoleniec/Stirling cycle to optimize the performance of the heat engine in real time. A state space analysis of the engine has been completed that demonstrates that the invention can operate successfully. So far, the analysis has predicted an output electrical power of 1.9 kW when operating between hot and cold temperature limits of 500°C and 20°C respectively. Under these conditions, the engine operates at a frequency of 87 Hz.

30. Development of a Research Turbidostat for Continuous Algal Cultures

The Libourel lab is developing a research program that demands a highly controllable experimental setup for algal cultures. To address this need, we are developing a turbidostat setup suitable for algal cultures. A turbidostat is a bioreactor with an actively controlled medium supply to maintain a stable cell density, regardless of the growth rate of the organism. This technology therefore allows for culturing cells at maximum growth rate. Maximum growth rate conditions are important for metabolic pathway utilization studies, and the effect of cell density on cultures is important for the translational research to develop industrial biofuels strains from laboratory strains. IREE contributed to this project by financing a triple quadrupole mass spectrometer that is used to (1) measure the oxygen production to determine metabolic activity, and (2) determine the fractional 13C/12C isotope labeling in CO_2 used for metabolic flux analysis studies that are performed in the lab. Oxygen production is used as a measure of cell density and is actively maintained at a set point value by diluting the culture with fresh media using a Labview operated PID.

31. Ethanol Dehydration to Ethylene in a Multifunctional Short Contact Time Reactor
This work focuses on a unique, stratified reactor that combines upstream catalytic partial oxidation via noble metals with downstream acidic dehydration via zeolites in order to process biomass compounds into biofuels in a single, compact reactor. Ethanol is used as a biomass model compound to examine the reactor's ability to remove water from biomass compounds during autothermal operation at millisecond contact times. Ethanol conversion, product selectivity, and reactor temperature profiles resulting from varying ethanol, sacrificial fuel and oxygen ratios are presented and discussed.

32. Splitting Water and Carbon Dioxide via the Heterogeneous Oxidation of Zinc Vapor
Solar thermochemical processes permit the storage and transportation of the vast solar resource as energy-dense fuels. A promising solar thermochemical process is the two-step zinc oxide redox cycle. This cycle produces synthesis gas (H_2+CO) from water and carbon dioxide using only solar thermal energy. Zinc oxide is first reduced to zinc and oxygen in a concentrating solar reactor, and then zinc splits water and carbon dioxide to produce synthesis gas fuel and regenerate zinc oxide for further reduction. We show that there are thermodynamic and kinetic advantages to splitting water and carbon dioxide via the heterogeneous oxidation of zinc vapor. The heterogeneous oxidation of zinc vapor eliminates entirely a limitation observed in alternative mechanisms using solid and liquid zinc, where the reaction is slowed or even halted as a layer of zinc oxide forms at the reaction interface. When zinc is oxidized in vapor form, zinc oxide formation does not impede further reaction; therefore, enhanced fuel production rates and higher zinc conversions are possible. The latter is shown to be crucial for achieving high solar-to-fuel efficiency. Furthermore, the heterogeneous oxidation of zinc vapor favors the production of synthesis gas over by-products such as methane.

33. PBC-DFT: An Efficient Method to Calculate Energy Band Gaps for Conducting Polymers Used in Solar Cells
In recent years, conducting polymers have gained attention for their promising application in solar cells due to their potential low cost, light weight and flexibility. Desirable polymers have a small band gap and a low HOMO energy level. Methods of finding this band gap exist using density functional theory (DFT) by calculating the energy gaps of increasing oligomer lengths (n) and plotting the HOMO-LUMO gap (in eV) as a function of the reciprocal polymer length (1/n). This method, however, proves time consuming and computationally costly. An alternative, less time-consuming method using periodic boundary conditions (PBC) exists. In our research, we studied existing donor-acceptor polymers from the literature and used PBC to calculate their band gaps for comparison with experimental data. To perform these calculations we used DFT at the B3LYP/3-21G(d) level of theory on optimized dimers. The PBC method yields results consistent with experimental values and can be useful in determining theoretical band gaps prior to synthesis, which can aid in saving valuable lab time.

34. Renewable Energy and Sustainable Chemistry Across the Undergraduate Chemistry Curriculum
Issues of energy and sustainability are having a direct impact on the public and are capturing the interests of many. As result, it is no surprise that science, including the field of chemistry, will become more connected with society in the future. To address this connection, we are in the process of integrating important elements of renewable energy and sustainable chemistry across the undergraduate chemistry curriculum at the University of Minnesota, Morris. This project strives to create a curriculum that is more interdisciplinary with respect to both teaching and research and that introduces topics that are timely yet essential in preparing undergraduate students. Our initial efforts are focused on three key areas: (i) developing new courses in renewable energy and sustainability; (ii) integrating photovoltaics across the undergraduate curriculum; and (iii) illustrating the role of biochemistry in renewable energy and sustainability. Our goal is to develop a far-reaching energy and sustainable chemistry curriculum that complements the traditional curriculum and better prepares our future graduates for success in addressing global problems. An overview of the project will be presented along with our preliminary results.

35. Air Quality Impacts of Biofuels Versus Conventional Fuels
Air pollution is associated with ecological and human health effects that impose costs on society. Here, we model potential air quality impacts from the production and use of biofuels versus conventional fuels. Our approach involves two steps. First, we estimate life cycle emissions in the production and use of each fuel considered. An important aspect of this work is predicting when and where emissions are likely to occur, since those attributes are necessary for understanding the air quality impacts of the emissions. Next, we use a comprehensive air quality model (CAMx) to estimate the changes in air quality that would be associated with potential shifts in emissions. Our poster will compare several fuels, comparing first- and second-generation biofuels against the conventional fuels that they may displace. In future work, we will investigate social costs and environmental justice aspects of the predicted changes in air quality. Our results provide new knowledge about the costs and benefits in air quality that may occur by switching from conventional fuels to biofuels.

36. A Novel Utility Interface for Plug-In Vehicles
Plug-in hybrid electric vehicles (PHEVs) can reduce our dependence on foreign oil. The potential power resource available in PHEVs is much larger than the current generation capacity. This project is investigating a novel interface between utility and PHEV—a battery pack that is capable of bidirectional power flow. The bidirectional power flow of the interface will allow PHEVs to feed power back to the grid during peak demand. The ultimate goal of this research project is to demonstrate a complete system with bidirectional power flow capabilities.

37. Compositional and Structural Phase Mapping of Cu_2ZnSnS_4 Photovoltaic Thin Films via Confocal Raman Spectroscopy
The chalogenide compound Cu_2ZnSnS_4 (CZTS), which is from Earth-abundant, nontoxic elements, is emerging as a prominent photovoltaic material for next-generation solar cells. A paramount requirement for successful CZTS solar cells is the synthesis and characterization of single-phase films. Due to the numerous stable compounds that exist in the Cu-Zn-Sn-S system, many with similar crystal structures, accurate identification of single-phase CZTS with standard methods such as X-ray diffraction, scanning electron microscopy and energy dispersive spectroscopy is difficult. We demonstrate that confocal Raman spectroscopy is a useful characterization technique for the unambiguous identification of CZTS amongst the other sulfide compounds. Our CZTS and copper tin sulfide (CTS) films are synthesized by ex situ sulfidation of copper, zinc and tin film stacks at 500°C for 8 hours. Under these conditions, sulfurized films are polycrystalline, stoichiometric, and, in the case of CZTS films, phase pure. Raman spectroscopy clearly identifies CZTS via a sharp characteristic peak at 338 cm^{-1}, while CTS exhibits a doublet structure depending on its crystal symmetry (monoclinic: 301 and 356 cm^{-1}, triclinic: 321 and 378 cm^{-1}). Using these characteristic peaks, confocal Raman spectroscopy can be used to spatially map CZTS and CTS domains in mixed-phase films for synthesis optimization.

38. Parasitic Resistance Effects on Split-Spectrum Solar Cell Performance
Semiconductor solar cells absorb photons of energy greater than their band gap and convert the photon energy to electrical energy less than the band gap. Consequently, small-gap solar cells can absorb a large part of the solar spectrum but deliver little energy per photon absorbed. Large-gap solar cells deliver more energy per photon but can absorb only the high energy part of the spectrum. Splitting the solar spectrum into multiple segments with diffractive elements that separate the incident radiation spatially and focusing it on solar cells optimized for the narrower bands facilitates the energy conversion. Here, we explore limitations to this approach imposed by inevitable parasitic effects. Specifically, we introduce series and parallel resistances into an ideal solar cell model. Resistance of the cell material and the contacts, and current leakage through the junction due to defects, can be captured by this model. Subsequently, current density characteristics, maximum power density and efficiency are determined. Highly conductive, low band-gap cells show performance degradation due to series resistance, while highly resistive large-gap cells are sensitive to junction leakage. As a specific case, we consider a three-cell solar cell array fabricated from $In_xGa_{1-x}N$ of varying composition.

39. Conversion of Waste Lignin to Liquid Fuels and Other High-Value Products
So far, bioenergy generation has strongly focused on conversion of fermentable sugars to ethanol. Lignin, the second largest portion of biomass, is considered a waste product and earmarked for combustion only. Sustainable use of biomass for bioenergy must include the conversion of all components of biomass to the highest value products feasible. We propose a two-pronged study geared toward conversion of waste lignin from the cellulosic ethanol process to a) a liquid fuel, capable of replacing petrochemical derived fuel, and 2) a high value filler/adhesive product to be used in conjunction with biodegradable plastics.

40. Development and Commercialization of an Integrated Biorefinery for Processing DDGS into Biofuels and Value-Added Products
The biorefining technology developed at the Natural Resources Research Institute (NRRI) can process the dried distillers grains and solubles (DDGS) byproduct from ethanol plants into a variety of higher value products including high-protein animal feed, additional liquid transportation biofuels and naturally occurring pharmaceutical components, and replace petroleum-based industrial chemicals. NRRI can now demonstrate this technology at a continuous pre-commercial scale level. If successful, the University of Minnesota will gain significant revenues from the consequent intellectual property (IP) while helping Minnesota meet renewable energy targets. Applying NRRI's integrated technology to an ethanol plant should result in the following: 1) improved energy efficiency coefficient by +15%; 2) increased annual profits of +$21M; 3) increased transportation biofuel output by +20%. Further benefits include reducing greenhouse gas emissions, reducing dependence on foreign oil imports by increasing domestic biofuel production, and improving the farm economy by stabilizing corn prices and providing higher value livestock feeds. Production of jet biofuel from "green diesel," offering the U.S. Armed Forces the opportunity to meet energy self-sufficiency goals, is also a possible outcome of this project. The final aim of this project is to optimize all parameters at sub-pilot-scale levels, pilot-scale levels and preindustrial-scale levels.

41. Partial Redox Cycles for Solar Fuels: Radiative Transfer and Properties
Cerium-based oxides are promising reactive porous materials for two-step partial redox solar thermochemical cycles to produce hydrogen or carbon monoxide. This poster summarizes the numerical techniques employed to study chemical kinetics and heat and mass transfer characteristics through a reactive porous medium. Experimental techniques to measure radiative properties of cerium-based oxides are also presented that serve as inputs to the numerical model. The experimental and numerical results will allow decisions regarding materials development, pore architecture and reactor design to be made with knowledge of the performance trade-offs.

42. Bio DME: A Next Generation Fuel From Biomass
The University of Minnesota Department of Mechanical Engineering is conducting an IREE-funded study entitled, "Performance and Emissions of a Second Generation Biofuel – DME." The objectives of this three year program, which began in July 2010, are to:
• conduct a business/economic analysis to demonstrate the viability of a Bio-DME as a transportation fuel in areas with substantial biomass resources like Minnesota
• evaluate life cycle greenhouse gas emissions associated with Bio-DME production and use as a transportation fuel
• convert a modern diesel engine to run on Bio-DME and measure performance and emissions with and without aftertreatment
• develop a second generation DME fuel injection system for the engine and measure performance and emissions with and without aftertreatment
• establish links between companies with gasification technology, companies with excess biomass that might benefit from producing DME, and end users that would benefit by fleet conversion

• promote the use of Bio-DME as a second-generation biofuel for transportation and the economic benefits of producing the fuel in Minnesota.

The test engine has been obtained and is being installed on an engine dynamometer. Preliminary investigations of the economics of production of DME in Minnesota are underway and will be described.

43. Corn Stover Densification Research at University of Minnesota, Morris
Corn stover has the potential to be an important biomass fuel in the Corn Belt region of the U.S. However, corn stover as a fuel has some serious drawbacks. It is difficult to handle because of its fibrous nature and its resistance to flowing even when finely ground. Stover's low bulk density makes transportation inefficient. Further, corn stover has high levels of silica and chlorine, creating the potential to slag on the grate and to corrode boilers and other components. Given these difficult attributes, corn stover must be densified into a stable, uniform product before transportation and use. UMM has partnered with both public and private collaborators to investigate various densification techniques. Among our partners are Renew Energy Systems, U of M West Central Research and Outreach Center, IREE, AURI, the Department of Bioproducts and Bioengineering at UM-TC and Minnesota Valley Alfalfa Processors. We are exploring pellets of various sizes, briquettes and other forms produced by both extrusion and pressing. The resulting products are being performance tested in UMM's 5 MW(th) Biomass Gasification Combined Heat and Power Plant.

44. Bio-Prospecting for Facultative Heterotrophic Microalgal Strains for Sustainable Biomass Production and Remediation of Concentrated Municipal Wastewater
Combining algae-based biofuel production with wastewater remediation offers a promising and environmentally friendly solution for sustainable renewable energy demand and reducing eutrophication burdens. One of the biggest challenges is to select appropriate algal strains that can adapt well in wastewater and can obtain high biomass and lipid productivity. In this study, 62 isolated strains from local habitats and 123 purchased strains from an algae bank were evaluated for their facultative heterotrophic ability in BG-11 medium (with organic carbon) and growth adaptation in highly concentrated municipal wastewater (HCMW). Among them, 54 strains can grow mixotrophically and hererotrophically under light/dark conditions. Thirty-four strains adapted well in HCMW, and the net biomass concentration ranged from 0.23 g/l to 2.14 g/L. One of them, UMN280, was chosen to cultivate in 25 L and 1200 L semi-continuous bioreactors in order to test stability and viability of scale-up. The results showed the system can be continuously run for two months with the maximum biomass concentration and lipid content of 1.7 g/L (volatile suspended solids VSS), 30% and 1.4 g/L, 19 %, respectively. Additionally, the nutrients removal was 70-90% for chemical oxygen demand (COD), 56-70% for total Kjeldahl nitrogen (TKN) and 60-70% for soluble total phosphorus (STP), respectively for both bioreactors.

45. New Metal-Ligand Complexes for Carbon Dioxide Reduction to Methanol
Fossil fuel depletion and increasing costs have driven scientists to seek alternative energy sources. One possible target is the use of methanol as a liquid fuel; however, current methanol production is too costly to be practical. Many scientists have looked to the reduction of carbon dioxide, an abundant and nontoxic one-carbon supply, as a renewable source for methanol production. One challenge of reducing carbon dioxide to methanol is the occurrence of bimolecular reactions to form undesirable products. Once formed, these products are difficult to convert to methanol. Our research focuses on the synthesis of novel "cage" ligands developed to prevent these unwanted products. Multidentate cage ligands have been synthesized and reacted with various transition metals. The resulting complexes will be investigated for carbon dioxide reduction.

46. A Nationwide Consortium of Universities to Reform Electric Energy Systems Education
The objective of this project is to revitalize U.S. power engineering education programs in institutions of higher education to meet immediate and near-future needs. This project will create a consortium consisting of a large number of universities, each of which will implement the state-of-the-art laboratories in power engineering developed at the University of Minnesota. In addition to these laboratories, which will be new at the participating universities, this project will also result in much-needed faculty development and new classroom materials in support of the power energy curriculum. This new energy framework will quickly start producing large numbers of graduates with a fundamentals-based education who can meet the multidisciplinary challenges inherent to our nation's efforts to make the nation's grid cleaner, smarter and more reliable. It will also be a foundation for graduate education and research in the areas of renewable energy such as wind, solar storage and energy conservation.

47. Evaluation and Demonstration of Small-Scale Solar Thermal Energy Systems
The University of Minnesota West Central Research and Outreach Center (WCROC) and the University of Minnesota, Morris (UMM) campus are developing a field test laboratory for small-scale renewable electric and thermal energy systems. The test-beds will allow for the practical utilization of the energy as well as being research, demonstration and certification platforms. The test-beds will allow for the "plug-and-play" insertion and removal of renewable energy systems and, when appropriate, the system integration of multiple systems. To develop testing protocols and to demonstrate current solar thermal technologies, two solar thermal systems have been purchased. The first system is a flat-plate solar thermal system manufactured by Solar Skies in Alexandria, Minnesota. The Solar Skies system provides domestic hot water via a Trend Setter hot water heat exchanger. The second system is an evacuated tube solar thermal system which was supplied by Solar Panels Plus in Chesapeake, VA. The Solar Panels Plus system is designed to provide 10 tons of air conditioning via an absorption chiller and 15 tons of space heat for the renewable energy addition of the WCROC office building. A Honeywell Energy Management System has been installed for system control, data acquisition and reporting.

48. Potential Formation of Longer Chain Hydrocarbon Gases from Anaerobic Bioreactors Using Clear Water Technologies Hogen Process
The production of biogas from animal waste materials and biomass is a common practice with well-recognized benefits and limitations. A functioning anaerobic digestion process catalyzes a complex series of microbiologically driven reactions with very little

human intervention or energetic input. These reactions typically produce a mixture of gases consisting of ~ 50% methane, 50% carbon dioxide and ~3000 ppm hydrogen sulfide. To be of higher value, the gas produced should contain more flammable products, less carbon dioxide and only trace amounts of corrosive sulfide. Clear Water Technologies, a Minnesota-based company, has reported that the addition of a small amount of magnetite plus a proprietary microbial inoculum to an anaerobic digester resulted in increased methane ratios and higher-value gases and nearly eliminated sulfide from the biogas end product. In the studies reported here we investigated whether the Hogen process of magnetite and microbe additions to bioreactors resulted in production of greater quantities of methane and higher-energy-containing gases from the anaerobic digestion of animal waste materials. To date, however, our studies have not found that the addition of either supplement results in a significant increase in the yield of methane or the production of propane or N-butane from anaerobic digestion of cattle manure.

49. Facilitation of Wind Power Development Through Use of Pump Hydro Energy Storage in Northeast MN
Pump Hydro energy storage is a well-known and low-cost solution for electrical energy storage. The technological components are available from various vendors. The adoption of a closed loop energy storage system using abandoned water-containing mine pits, however, has not been studied in great detail and various issues and factors must be understood before such a system can be adopted in the state of Minnesota and elsewhere in the U.S. This project focuses on the policy, environmental, economic and geotechnical issues that must be considered in potentially implementing this technology in Minnesota's vast iron ore districts in the northern part of the state. It is also well known that wide-scale use of wind energy and its intermittent generation will require effective energy storage, and pump hydro is potentially a large-scale, cost-effective method for achieving this storage capability.

50. Reducing Greenhouse Gas Emissions: Lessons From State Climate Action Plans
Our research examines how state-level factors affect greenhouse gas (GHG) reduction policy preference across the U.S. by analyzing climate action plans (CAPs) and surveying the advisory group members who took part in creating them. It offers insight into how states approach the problem of choosing emissions-abatement options that maximize benefits and minimize costs, given their unique social, economic and geographic circumstances, as well as the constellation of interest groups with power to influence state policy. The state CAPs recommended 10 popular GHG reduction strategies to accomplish approximately 90% of emissions reductions, but they recommended these strategies in distinctly different proportions: a strategy that is heavily relied on in one state's overall portfolio may play a negligible role in another state. This suggests that any national policy to limit GHG emissions should encompass these key strategies but with flexibility to allow states to balance their implementation in a way that is appropriate for their unique geographic, economic and political circumstances. Survey results strongly support the conclusion that the mix of actors at the table influences GHG reduction policy decisions. Survey results also provide evidence that physical and/or geographic factors may underlie the varying reliance on certain GHG reduction strategies.

51. Combining CO_2 Sequestration with Geothermal Energy Production
Thermodynamic analysis has been conducted for several renewable geothermal power cycles using a portion of deep ground sequestered carbon dioxide (CO_2) as the working fluid. The advancement of clean coal technologies has increased the demand for CO_2 sequestration, which in turn has increased the number of necessary sequestration sites. This has the potential to greatly expand geothermal electricity production for much of the world. Using CO_2 as the working fluid allows energy production at much shallower depths and in geologic areas with much lower temperature gradients than those of current geothermal systems. Two different geothermal power systems were analyzed for system efficiency, power production and component costs. The first system is a direct single loop system with CO_2 run directly through the turbine. This system was found to have the highest efficiency and power production, but the necessary custom high-pressure components could drive up system expenses. The second system is a binary geothermal system with CO_2 used to transfer heat to an Organic Rankine Cycle (ORC). This system was found to have slightly less power production and was slightly less efficient than the direct system but required fewer custom components, potentially lowering system costs.

52. Wide Band Gap CIGS Based Absorber for Photovoltaic Application
Copper ternary chalcogenide–based solar cells became a recent solution to the high cost problem of solar cells. Copper indium diselenide solar cells have an architecture of several layers, which are sorted by CIGS (copper indium gallium selenide) as absorber layer, CdS (cadmium sulfide) as buffer layer, ZnO (zinc oxide) and ITO (indium tin oxide) layers as window layer and top contacts for the device. With the recent laboratory scale improvements, the efficiency of CIGS solar cells rose to 19.9% by NREL. One of the current research areas is based on sustaining the same efficiency on a bigger scale. In this work, the CIGS layer is deposited on Mo sputtered four-inch soda-lime glass substrates. CIGS deposition step is done by physical vapor deposition of elemental species in an ultra-high vacuum system. CdS is deposited using chemical bath deposition. Top window layers ZnO, ITO and Ni/Al are sputter deposited. In this work we are attempting to develop a wide band-gap absorber material based on CIGS with low trap density and good interface lattice matching. Al-doped CIGS devices will be fabricated to investigate the effect of Al doping on trap density.

53. Model-Based Flow Control for Improved Wind Turbine Efficiency
Renewable energy sources are becoming increasingly important in our society. The progressively larger size of wind turbines introduces significant challenges for their design and control and brings out new opportunities for development of advanced technologies. Presented is our ongoing research for improving the aerodynamic efficiency and reliability of the wind turbines by passive and active flow control, thereby improving the generated energy and turbines' longevity. These efforts include (i) using vortex generators for control of separation over blades; (ii) turbulent skin-friction drag reduction by means of riblet-mounted blades; (iii) using cilia-coated blades for lift enhancement and reduced turbine vibrations; (iv) coating non-streamlined structures with porous media to weaken wake turbulence and reduce pressure drag; and (v) feedback flow control by means of blade-mounted arrays of sensors and actuators. We summarize our efforts in modeling and control of the onset of turbulence. Since early stages of transition are initiated by large flow sensitivity, we have developed a paradigm for designing sensorless and feedback control strategies that

significantly reduce this large sensitivity. Our results confirm that these strategies are capable of preventing transition with positive net efficiency. Our theoretical developments will find use in analysis and design of flow control strategies for improved wind turbine efficiency.

54. Seasonal Solar Thermal Storage Using $CaCl_2$ Liquid Desiccant
Residential energy use accounts for 22% of all energy consumed in the U.S. Today, only 1.5% of the energy consumed in buildings is provided by solar. Solar thermal systems are the most efficient use of solar energy to meet space heating, cooling and hot water loads, which together account for 60% of the energy used in homes. The major challenge to expanding market penetration is the temporal mismatch of the load and the solar availability. To address this challenge, long-term and compact thermal storage materials must be developed. In this project, we investigate the use of aqueous calcium chloride liquid desiccant as a storage material for use in closed-cycle solar thermal heating systems. We have developed a prototype storage tank with an immersed polymer heat exchanger to manage sensible energy and solutions of varying calcium chloride concentration. We are interested in preventing calcium chloride mixing between layers in the tank while heating the tank via the immersed heat exchanger. We describe the experimental program to characterize calcium chloride mixing and present some initial experimental results.

55. Pressure-Sensitive Adhesive from Renewable Triblock Copolymers
A pressure-sensitive adhesives system was designed using renewable resources derived from natural products such as corn, mint and rosin. Polylactide-polymenthide-polylactide triblock copolymers were synthesized as elastomers bases for pressure sensitive adhesive formulations. The polymers were characterized by NMR spectroscopy and size exclusion chromatography. All polymers showed narrow molecular weight distributions. Phase-separation was elucidated with small-angle X-ray scattering and differential scanning calorimetry. We determined that transesterification was minimized during polymerization of lactide from a polymethide macroinitiator, thus providing well-defined block polymers. The elastomers were formulated with a renewable tackifier. Probe tack, peel adhesion and shear strength tests were carried out to evaluate the adhesive performance.

56. Improving Organic Solar Cells With Graded Interfacial Modifications
The conversion of solar energy to electrical current and voltage depends on the interplay between chemistry and physics at the interface between donor (D) and acceptor (A) materials. Yet there have been only limited efforts to modify this interface to enhance its performance, and the molecular origins for these reported enhancements are not well understood. In this project, we focus our attention on developing a fundamental understanding of the D-A interface with an eye toward systematically tailoring its chemistry to boost solar energy conversion efficiencies. These interfacial modifications will be applied as thickness gradients so their influence and optimal conditions can be identified quickly from a single sample. In conjunction with the unique sample preparation, we will employ a powerful spectroscopic technique, vibrational sum frequency generation (VSFG), to measure changes in interfacial structure during device assembly and operation.

57. Regulation of Cell Wall Composition in Nitrogen Fixing Biomass Crops in Minnesota
Biological nitrogen fixation enables sustainable cropping because it reduces the need for chemical fertilizer application, resulting in less runoff and improved water quality. Nitrogen-fixing plants native to Minnesota include legumes, found in prairie ecosystems and elsewhere, and actinorhizal shrubs, including speckled alder (*Alnus incana* subsp. rugosa), a native to Minnesota. Alfalfa *(Medicago sativa),* a forage crop, is also being investigated for sustainable biomass production. Studying alfalfa is challenging because it is a cross-pollinated autotetraploid plant. Evaluation of the closely related diploid *Medicago truncatula,* with well-developed genetic and genomic resources, would facilitate analysis of biomass traits. Our long-term goals are to identify plant genes and gene networks regulating plant cell wall composition and biomass production in the model legume *Medicago truncatula* and to develop translational approaches for genetic improvement of nitrogen fixing biomass crops already adapted to Minnesota. Cell wall composition and structure affect cost and efficiency of biomass conversion. Improved understanding of factors controlling cell wall development in legumes will facilitate increased biomass quality (e.g., reduced lignin, modified crystallinity of cellulose, or reduced fermentation inhibitors), and biomass production (e.g., cellulose quantity). We envision that this project will allow cell wall trait modification via development of molecular markers for breeding or through transgenic approaches.

58. Characterization of a Microalgae *Chlorella* sp. Well Adapted to Highly Concentrated Municipal Wastewater for Nutrient Removal and Biodiesel Production
This research was aimed at testing the feasibility of growing *Chlorella* sp. in the centrate, a highly concentrated municipal wastewater stream, for simultaneous wastewater treatment and energy production. The characteristics of algal growth, biodiesel production and wastewater nutrient removal; the viability of scale-up; and the stability of continuous operation were examined. Three culture media, namely Tris-Acetate-Phosphate (TAP) medium, autoclaved centrate (AC) and raw centrate (RC) were used for comparison in the studies. The results showed that algae could remove ammonia, total nitrogen, total phosphorus and chemical oxygen demand (COD) by 93.9%, 89.1%, 80.9% and 90.8%, respectively, from raw centrate in a 14-day batch culture. The fatty acid methyl ester (FAME) content for algae cultivated in centrate was 11.04% of dry biomass, and the biodiesel productivity was 0.12g/L. The system could be successfully scaled up and continuously operated at 50% daily harvesting rate, providing a net biomass productivity of 0.92 g-algae/(L•day).

59. Exploiting Genetic Variation in Soybean to Increase Oil
The focus of this project is on developing soybean varieties with improved seed composition (protein and lipid contents) and yield traits. To be able to breed new varieties with the best possible seed composition and yield characteristics, it is necessary to have more information regarding the genes that control these traits. Regulation of gene activity levels plays a critical role in determination of desirable traits. In brief, a major part of the reason that two varieties differ in these traits is that the varieties differ in the activity levels of important genes. So, by identifying the genetic loci that control variation in gene activity, it should be possible to identify many of

the genetic loci that control variations in seed composition and yield. These genetic loci that help regulate the expression levels of different genes are known as “expression quantitative trait loci”, or “eQTL.” Once these eQTL are identified, molecular markers that map to the same regions of the genome will be identified and used to facilitate breeding programs to develop new soybean varieties with desirable seed composition and yield traits. The development of these improved soybean lines will aid production of biodiesel fuel from soybean.

60. Using Genomics to Increase Soybean Biodiesel Yield
Soybean is particularly attractive as a source of renewable energy because its seeds contain up to 25% oil. The energetics of growing soybean are also unusually good, because soybean is one of the few crops that receives nitrogen through biological nitrogen fixation. A primary need in developing soybean as a viable source of renewable energy is that the costs of producing soy diesel must be reduced. This goal may be achieved by increasing the amount of oil produced by soybean or by increasing the value of co-products, such as soy protein meal. We are making use of the resources available in the model plant *Arabidopsis thaliana* to identify genes involved in controlling seed composition, size or yield. Based on preliminary analyses, we identified 189 genes from among approximately 24,000 genes carried by *Arabidopsis* that appeared promising to play important roles in helping control seed yield, composition (protein and oil amounts) and size. Further experimentation resulted in the identification of several genes that are particularly promising. In the future, these genes will be tested for the ability to alter seed composition, yield or size in soybean.

61. The Virtual Wind Simulator for Wind Farm Optimization
One of the main sources of uncertainty during the design (turbine siting) and operation of wind energy projects is associated with the currently limited and imprecise prediction of wind and turbulence at spatial and temporal scales relevant to wind turbine operation. In addition, there is poor understanding of how the high spatial and temporal variability in wind and turbulence affects wind turbine performance (energy output) as well as the fatigue loads on the structures. Additionally, the interplay between wind and the underlying terrain results in wind fields that can have large variability within short distances (a few meters) and short time scales (a few minutes), affecting local potential for wind energy production. This project aims at developing a “virtual wind simulator” that can be used to predict atmospheric boundary layer flow and its interactions with wind turbines and wind farms. The project team will develop and validate an advanced, state-of-the-art computational framework for carrying out high-resolution numerical simulations of wind turbulence across the entire range of scales that are relevant for wind turbine project design and diagnosis, including regional (103 m) and local wind-farm scales (102 m) as well as the scale of individual wind turbines (100 m).

62. The Eolos Wind Energy Research Consortium
This project team seeks to develop an industry/academe wind energy consortium led by the University of Minnesota – Twin Cities that will work to accelerate the path toward meeting the Department of Energy’s (DOE) 20 percent wind by 2030 goal through cutting edge research, field-scale demonstration of new technologies and workforce training.

Several research facilities will be developed to create a transformative and industry-driven research agenda aimed at addressing several major challenges confronting the wind power industry today, with special emphasis on turbine reliability and wind power integration. Three project tasks will be completed:
1. Develop state of the field- and laboratory-scale wind energy research facilities that enable testing, demonstration and data collection of a wide range of wind turbine technologies.
2. Use these facilities to develop a bold and transformative industry-driven research agenda.
3. Create new curricula and education initiatives for training the next generation of wind industry technical support staff and engineering leaders.

63. The Roosevelt Island Tidal Energy Project: Hydrokinetic Turbine Design Using Advanced Engineering Analysis
University of Minnesota researchers at the St. Anthony Falls Laboratory are collaborating with Verdant Power Inc. to design the next generation of hydrokinetic turbines for the Roosevelt Island Tidal Energy project in New York City. State-of-the art computational fluid dynamics analysis along with laboratory experiments in the SAFL main channel are used to improve the hydrodynamic performance of the complete turbine configuration, understand turbine array hydrodynamics and assess and mitigate environmental impacts of the turbines on the aquatic ecosystem.

64. Durability of Polymers for Solar Thermal Applications
All polymeric systems have been proposed for solar domestic hot water systems. For components such as a load side heat exchanger or the absorber, polymer tube geometries are selected to satisfy the competing requirements of strength and thermal resistance: Thicker tubes are desirable for satisfying strength requirements, while thinner tubes are desired to minimize the conductive thermal resistance across the tube wall. For these applications, the durability and lifetime of polymer components depend on the ability of the polymer to maintain adequate material strength in the fluid medium. In this project, we are concerned with durability and lifetime of polymer tubes in potable water. This concern arises anytime the polymer heat exchanger is exposed to an open loop flow, such as in load side heat exchangers or the collector loop in direct solar systems. The chlorine and pH in potable water combine to create an oxidative environment that can cause the polymer to degrade. The degraded polymer is brittle and failure occurs when microcracks form and propagate. In our work, we are studying the relationship between the extent of degradation and the crack growth.

65. Creating Low Cost Solar Heating Through Materials Innovation
This project addresses the need for developing solar thermal systems for residential heating and hot water that are low cost and compatible with all U.S. climates. In particular, the research focuses on materials development to enable design of glazed polymeric collectors. Our focus on efficient, cost-effective polymeric collectors is driven by both the promise of major reductions in installed cost (at least 50%) with a shift from copper and glass components to integrated systems manufactured using mass production techniques

and the limitations of polymer collectors on the market today in mild climates. The major impediment facing development of glazed polymer collectors is the lack of an adequate approach to protect the polymeric absorber from overheating. To address this impediment, we are proposing to develop thermotropic materials for which the index of refraction changes as a function of temperature. Overheat protection is provided when the material changes from clear below the switching temperature to opaque above the switching temperature.

66. Combining Geothermal Energy with Geologic CO_2 Sequestration: High Geothermal Power Production Efficiency at Low Cost

A research team at the University of Minnesota is developing a method to combine geologic carbon dioxide (CO_2) sequestration with geothermal energy use: CO_2 Plume Geothermal (CPG). CO_2 is injected into deep, permeable geologic formations. A portion of the geothermally heated CO_2 is piped back to the surface, sent through a turbine to power a generator, then returned to the subsurface. This new approach represents a radical shift in electric/heat power generation because it not only utilizes a renewable energy source but has a negative carbon footprint. The technology has the potential to reduce greenhouse gas emissions by displacing fossil-fuel-based power production and by sequestering greenhouse gases from conventional energy technologies, industry and biofuel plants. Furthermore, the technology would 1) provide a highly scalable electricity source for base-load or dispatchable power; 2) significantly reduce temperatures required for economical geothermal electricity generation; 3) result in geothermal power plant efficiencies two to five times those of conventional water-based systems; and 4) provide an electricity source with efficiencies that scale with demand. Finally, preliminary modeling indicates that the levelized cost of electricity produced by CPG systems would be very competitive with other energy technologies.

67. Hydrothermal Carbonization of Microalgae: Fatty Acid, Char and Algal Nutrient Products

A process for isolation of three products (fatty acids, chars and nutrient-rich aqueous phases) from the hydrothermal carbonization of microalgae is described. Fatty acid products derived from hydrolysis of fatty acid ester groups in the microalgae were obtained in high yield and were found to be principally adsorbed onto the char also created in the process. With the highest lipid-containing microalga investigated, 92% of the fatty acids isolated were obtained by solvent extraction of the char product, with the remaining 7% obtained by extraction of the acidified filtrate. Obtaining the fatty acids principally by a solid-liquid extraction eliminates potential emulsification and phase separation problems commonly encountered in liquid-liquid extractions. The aqueous phase was investigated as a nutrient amendment to algal growth media, and a 20-fold dilution of the concentrate supported algal growth to a level of about half that of the optimal nutrient growth medium. Uses for the extracted char other than as a solid fuel are also discussed. Results of these studies indicate that fatty acids derived from hydrothermal carbonization of microalgae hold great promise for the production of liquid biofuels.

68. Evaluation of Cob Biomass Yield and Composition Within Modern Corn Hybrid Varieties

Corncobs have several desirable characteristics when compared with other agricultural biomass energy feedstocks. Cobs make up approximately 12% of the corn stover remaining in the field after harvest. Therefore, removal of cobs will reduce concerns of organic carbon depletion while maintaining valuable nutrients within soil when compared to corn stover removal. Several studies are in progress to evaluate cob harvest, storage, utilization, sustainability and yield potential. The objective of this project was to conduct a corn variety trial with the emphasis on cob yield and composition. In fall 2009, the West Central Research and Outreach Center evaluated 56 corn hybrid varieties. Cobs from three replicated plots of each variety were harvested, weighed and dried. Yields and dry matter composition were then determined. Dry matter cob yield between hybrid varieties ranged between 904 lbs per acre to 1,522 lbs per acre for a difference of 618 lbs. Considering a realistic market price of $55 per dry ton and a $45 per dry ton payment from the USDA BCAP program, the resulting difference between the high and low cob yield varieties was projected to be $30.90 per acre ($45.20 and $76.10 total per acre respectively) or $30,900 per 1,000 acres of corn.

69. Next-Generation Biofuels and the Ecosystem Services They Provide: Sustainability and the Biomass Production Landscape

The goal of this study is to evaluate the impact of biomass production options throughout the Mississippi River watershed. This is in an effort to quantify the economic costs and benefits, both direct and external, of different placements of various biomass production regimes on the Midwestern landscape. As such, we will describe scenarios for optimal placement that maximize net benefits returned to farmers, biorefineries and the public. To determine the impacts of biomass production, we will calibrate existing landscape/atmospheric interaction (Agro-IBIS) and economic (InVEST) models to site- and source-specific parameters. Our assessment will address the following categories of bioenergy feedstocks: crop residue, double/mixed cropping systems, perennial plants and sustainably harvested wood. With our results, we aim to inform stakeholders on what bioenergy feedstocks to use, where to produce them, what environmental impacts will arise and how biomass systems will contribute to climate change.