2011 S-1041 Annual Progress Report

Participants:
LINDSAY ANDERSON , CORNELL UNIVERSITY; PETER ARBUCKLE, UNITED STATES DEPT OF AGRICULTURE - NIFA, HASAN ATIYEH, OKLAHOMA STATE UNIVERSITY; PUSHPAK BHANDARI, OKLAHOMA STATE UNIVERSITY; DORIN BOLDOR, LOUISANA STATE UNIVERSITY; BILL BROWN, UNIVERSITY OF TENNESSEE; ROBERT BROWN, IOWA STATE UNIVERSITY; IGATHINATHANE CANNAYEN, NORTH DAKOTA STATE UNIVERSITY; SERGIO CAPAREDA, TEXAS A & M UNIVERSITY; JULIE CARRIER, UNIVERSITY OF ARKANSAS, CHENGCI CHEN, MONTANA STATE UNIVERSITY; JONATHAN CHEN, UNIVERSITY OF TEXAS; MING-HSU CHEN, UNIVERSITY OF ILLINOIS; EUGENE COLUMBUS, MISSISSIPPI STATE UNIVERSITY; MAMATHA DEVARAPALLI, OKLAHOMA STATE UNIVERSITY; JULIA FAN, UNIVERSITY OF CALIFORNIA; JIE GAO, OKLAHOMA STATE UNIVERSITY; BILL GIBBONS, SOUTH DAKOTA STATE UNIVERSITY; MOHUA HAQUE, THE SAMUEL ROBERTS NOBLE FOUNDATION; DAVID JONES, UNIVERSITY OF NEBRASKA; DEEPAK KESHWANI, UNIVERSITY OF NEBRASKA; SAMIR KHANAL, UNIVERSITY OF HAWAII; AJAY KUMAR, OKLAHOMA STATE UNIVERSITY; RANDY LEWIS, BRIGHAM YOUNG UNIVERSITY; NINGBO LI, KANSAS STATE UNIVERSITY; QING LI, UNIVERSITY OF HAWAII; SONG LI, UNIVERSITY OF ILLINOIS; YEBO LI, THE OHIO STATE UNIVERSITY; YONGHUI LI, KANSAS STATE UNIVERSITY; CARL LIRA, MICHIGAN STATE UNIVERSITY; KAN LIU, OKLAHOMA STATE UNIVERSITY; LANCE LOBBAN, UNIVERSITY OF OKLAHOMA; MICHAEL MUELLER, OKLAHOMA STATE UNIVERSITY; KASIVISWANATHAN MUTHUKUMARAPPAN, SOUTH DAKOTA STATE UNIVERSITY; IOAN NEGULECU, LOUISIANA STATE UNIVERSITY; SUE NOKES, UNIVERSITY OF KENTUCKY; VAMSEE PASANGULAPATI, OKLAHOMA STATE UNIVERSITY; KRUSHNA PATIL, OKLAHOMA STATE UNIVERSITY; MIKE PENNER, OREGON STATE UNIVERSITY; RANDY PHILLIPS, OKLAHOMA STATE UNIVERSITY; GUANGYAN QI, KANSAS STATE UNIVERSITY; KARTHIC RAMACHANDRIYA, OKLAHOMA STATE UNIVERSITY; ALI ROWNAGHI, OKLAHOMA STATE UNIVERSITY; ROGER RUAN, UNIVERSITY OF MINNESOTA; TROY RUNGE, UNIVERSITY OF WISCONSIN; ASHOKKUMAR SHARMA, OKLAHOMA STATE UNIVERSITY; SUSAN SUN, KANSAS STATE UNIVERSITY; RALPAH TANNER, UNIVERSITY OF OKLAHOMA; BERNIE TAO, PURDUE UNIVERSITY; JENNY TERRILL, OKLAHOMA STATE UNIVERSITY; DAN THOMAS, OKLAHOMA STATE UNIVERSITY; MIKE TUMBLESON, UNIVERSITY OF ILLINOIS; JAYA TUMULURU, IDAHO NATIONAL LABORATORY; DONGHAI WANG, KANSAS STATE UNIVERSITY; BOB WHITSON, OKLAHOMA STATE UNIVERSITY; MARK WILKINS, OKLAHOMA STATE UNIVERSITY; AL WOMAC, UNIVERSITY OF TENNESSEE; FEI YU, MISSISSIPPI STATE UNIVERSITY; KE ZHANG, KANSAS STATE UNIVERSITY; STEPHEN ZHU, OKLAHOMA STATE UNIVERSITY

Minutes of Meeting:
Introductory remarks and welcome by Mark Wilkins, Chair

Scott Frazier, Assistant Professor at Oklahoma State University, asked participants to participate in a survey on biomass.

Present: Participants introduced themselves, see attached list for full list

Comments and remarks from Dr. Bill Brown, administrative advisor: it is encouraging to see so many states and the diversity of participants in the group. Some of the participants cut across extension, not only on research. This is a very cohesive group among all the multistate projects. This multistate project allows people to collaborate more easily on research projects. This meeting is an excellent opportunity to share information and to generate new ideas. This group can be considered a model for other multistate groups.

Comments and welcome from Dr. Dan Thomas, OSU BAE Department Head. Reiterated some of the comments made by Dr. Bill Brown. The survey handed out will be tied out as an outcome from this group. It is an opportunity to have a multistate activity.

Mark Wilkins: station reports status – we will need a 5 minute report from each station, and for the written report we will need a one page report to be compiled in the project report. The written reports are due by August 15th to Mark Wilkins, and to NIMSS by September 1st.

Bill Brown: we do need to submit a report in the multistate system, which can be a compilation of the one-page station reports. We do need to give it a little bit of attention in the next 30 days. These reports are used by USDA, NIFA, and they are public domain and accessed by the larger public.

Dan Thomas: this reporting is a worth-while effort for the long term benefit of the group and the field.

Remarks by Dr. Robert Whitson, OSU Dean of Agriculture: the efforts made by this group in the biofuels area are important, and at OSU we put a lot of emphasis and resources in the biofuels and bioproducts area. The current federal fiscal environment is really difficult, the special initiative federal funding have been cut or significantly reduced. Everybody is watching what is happening to the first plant that produces lignocellulosic ethanol and how economically competitive it will be. The great thing about this group is that it can take an interdisciplinary approach to the biofuels production. No one institution can afford to put resources in all the different fields required, and the institutions have to work together, particularly the scientists. At the state level, the producers are interested in the risks they are taking when producing a new crop, and the economic return they can gain from the bioenergy and bioproduct dedicated crops. OSU is opening a new Biosciences Institute at the border with Texas to research biofuels and byproducts using money from the state to have priority with the Nobel Foundation. We also need to train our next generation of scientists. Oklahoma is at the crossroads of biofuels and bioproducts, and it is well positioned to take advantage of the accumulated expertise in the future.

Peter Arbuckle USDA – NIFA: Power point presentation

Questions from the audience.

David Jones (Nebraska) on the BRDI project reviews: 19 projects to be reviewed. Reviews to be done by the end of the year (the groups established by the end of the month).

Afternoon session:
Mark Wilkins leading discussion on the new project: We can go into a two year development group. We would like to discuss what kind of objectives we would like to see in the next 5-year cycle. Review of the current objectives. Julie Carrier has offered to lead the proposal development, with help from the committee.

Bernie: what is the target outcome product? Do we stay only with the "fuels" or decrease the emphasis on "bio-fuels".

Mark: having people from other fields (land conversion, climate change, economics, sustainability, etc.) would require creating an objective.

Bernie: is it necessary to have an objective on analyzing and characterizing bio-materials and their functionality? We need to have some niche applications (plasticizers, surfactants, lubricants) that are bio-based.

Julie: the funding is going toward consortium …

Bernie: do we need to create a white paper on what is the long-term strategies? Can we help direct the funding in certain areas?

Julie: we do keep the education component?

Dorin: we should include also science-based educational material for the general public.

Bernie: We could create some materials for certain technologies (brochures) for general public and k-12 programs.

Julie: these could be used in other proposals as broad impact (for NSF especially). For today's meeting we would like to have the objectives set.

Objective 1 to be kept, to add land-use, water resources, etc.
Objective 2 and 3 could be integrated by re-naming "fuels" into one of the chemicals.
A new objective could be added into a dissemination

Susan: Objectives 2 and 3 are similar. What are the fundamental challenges and issues in the production process? In order to be successful a plant would need to produce more than fuel (ethanol)…

Bernie: the question is who is the entity that is going to support the work on bio-based

DOE is highly focused on biofuels (we can use the term advanced or drop-in biofuels)

Julie: leading the development and writing the new objectives.
New objectives were established and are attached to this meeting.

Station reports: 5 minute briefs were provided, written reports are attached.
Business meeting:

Mark Wilkins calls the meeting to order.
Present: see attached sheet.

Bernie: motion to adopt previous meeting minutes.
David: second.
All in favor.
No objections, no discussion. Minutes approved.

Writing of next project: Julie will lead the writing. Primary objectives established prior. See above.

Al Womac will lead the first objective (logistics and harvesting). Contributors:

Al Womac, Igathi Canneyan, Kasiviswanathan Muthukumarappan, Deepak Keshwani, Chenci Chen

Roger Ruan will lead second objective (processing and bioproducts). Contributors:
Mark Wilkins, Hasan Atiyeh, Ajay Kumar, Bernie Tao, Jonathan Chen, Samir Khanal, Qing Li, Dorin Boldor.

Lindsay Andersen will lead the third objective (system analysis). Contributors:
David Jones (Nebraska), Deepak Keshwani (Nebraska), Hasan Atiyeh (Oklahoma), Julia Fan (UC Davis), Chengci Chen (Montana), Ganti Murthy (Oregon), Christine Kelly (Oregon)

Muthu will lead the forth objective (education). Contributors:
Muthu, Mark, Julie, Sun

Objective leaders will provide a list with names.

Samir will take the lead on keeping the people up to speed on writing the project objective.

Bernie moves to nominate Chengci Chen,
Julie seconds.
All in favor.
No objections.
Motion approved.

2012 Meeting is established at Washington DC.
ASABE meeting is July 29 to August 1st.
Samir: Motion to approve the date as August 6 and 7, 2012
Deepak: second.
All in favor, no objections. Motion approved.

Roger will head the 2012 symposium committee. Tentative topic is systems analysis and life cycle analysis.
Julie suggested that instead of a symposium we can use the opportunity for a few of the group members to present highlights of what we do to the National Program Leaders in various agencies.

Location of 2013 Meeting.

Group members from Hawaii presented some of the costs involved for travel to a potential meeting to Hawaii.

Sue Nokes moves to have the meeting in Hawaii
Bernie seconds.
All in favor. Motion approved.

Julie motions to adjourn the meeting.
Sue Nokes seconds.
All in favor. Meeting adjourned.

Accomplishments

Objective A. Reduce costs of harvesting, handling, and transporting biomass to increase competitiveness of biomass as a feedstock for biofuels, biomaterials and biochemicals.

Task 1: Quantify and characterize biological feedstocks.

(HI) Our research team is examining the change in biomass (Napier grass) composition with time at different stages of growth. By knowing the maximum level of carbohydrate in the biomass, we can optimize the biomass harvesting age and thus the overall biomass yield for biofuel and biobased products. Such study can provide valuable data that can be useful for all tropical regions. (TN) Near infrared (NIR) spectroscopy, coupled with multivariate analysis and data pretreatment, was evaluated to remove interference from physical heterogeneity that could mask chemical property responses. Pretreatment methods included standard normal variate (SNV), multiplicative scattering correction (MSC), 1st derivative with Savitzky-Golay algorithm (1st derivative), 2nd derivative with Savitzky-Golay algorithm (2nd derivative), extended multiplicative signal correction (EMSC) and combinations of 1st derivative/2nd derivative with SNV. Results indicated that, of these methods, EMSC was most effective for diffuse reflectance NIR analysis of lignocellulosic biomass. The EMSC-pretreated data not only best accessed the chemical similarity of the probed feedstocks in our hierarchical cluster analysis but also consistently led to the overall best prediction of the chemical composition of biomass. Based on our previous study, we hypothesized that a broad-based FT-NIR predictive model can be developed to analyze multiple types of biomass feedstock. The two most important biomass feedstocks--cornstover and switchgrass--were evaluated for the variability in their concentrations of the following components: glucan, xylan, galactan, arabinan, mannan, lignin, and ash. A hypothesis test was developed based upon these two species. Both cross-validation and independent validation results showed that the broad-based model developed is promising for future chemical prediction of both biomass species; in addition, the results also showed the method's prediction potential for wheat straw. (MT) Montana State continues to evaluate camelina and other oilseed crops as potential feedstock for biodiesel and aviation fuels. The major work includes: 1) camelina cultivar evaluation for higher yield and better oil content/profile; and 2) cropping system development for camelina feedstock production. MT are testing camelina varieties and breeding lines at multiple locations across Montana for adaptation and yield potential. Since wheat is the major cash and food crop in the Northern Great Plains, it is not feasible to replace wheat acres with camelina for biodiesel or jet fuel feedstock production. MT is studying cropping systems that use camelina as a rotation crop for wheat to replace summer fallow. A rotation study was established in 2008 to study the effect of camelina on wheat, and the economic return using camelina as rotation crop in wheat-based cropping systems. The advantage of camelina as a biofuel feedstock is that the existing farming and handling equipment/facility can be used, and minimal equipment modification is needed. Data from this study will provide guideline to farmers and biofuel companies what camelina price should be received in order to make the production system profitable/competitive. (ND) Utilizing the North Dakota Industrial Commission and USDA-ARS grant, the "NDSU Biomass Testing Laboratory at NGPRL" (Northern Great Plains Research Laboratory, USDA-ARS, Mandan, ND) is being established. The four major equipment procured are (1) Thermal analyzer – (thermo gravimetric and differential scanning calorimetric analysis), (2) Calorimeter – (heat/energy value of biomass), (3) Universal testing machine – (mechanical characteristics of biomass), and (4) Environment control chamber – (storage characteristics of biomass). The thermal analyzer was installed and tested, while the other equipment were in the process of installation. The envisioned activities of the lab are to characterize the several species of ND biomass for physical, mechanical, and thermal properties. More results will be reported in the future. (NY) An experiment was initiated at the Cornell University Willsboro Research Farm to investigate the impacts of soil type and fertility treatments on biomass productivity and composition of switchgrass, tall fescue and reed canary grass. Treatments applied in the spring of 2009, 2010, and 2011 on a well-drained sandy soil and a relatively poorly drained clay soil included N, N/P, and N/P/K fertilization, fresh dairy manure application, and composted dairy manure application, with check plots receiving no treatments. Cool-season grasses were harvested twice/season, while switchgrass was harvested once in October each year. Switchgrass yield was highest, and was least affected by treatment, while the manure, compost and check treatments produced lower yields than commercial fertilizer treatments for cool-season grasses. Composition was greatly affected by species and treatment, with fewer differences due to soil type. Manure treatment generally resulted in highest ash, K and Cl, with compost ranking second among treatments for ash, K and Cl. Chlorine, a problematic element for combustion, ranged from 13.6 g/kg in first growth of cool-season grasses with manure, to 0.7 g/kg in switchgrass with or without N fertilizer applied. Manure and compost treatments resulted in consistently very high Cl in the biomass. While gross energy content was significantly lower in biomass produced from organic vs. inorganic fertilizer sources for cool-season grasses, the range among all treatments did not exceed 5%. There were no differences among treatments for gross energy content of switchgrass. Samples were taken at the time of mowing for this experiment, mowing with delayed baling would significantly reduce concentrations of leachable elements such as K and Cl. (CA) Thermal properties of biomass feedstocks including forest and agricultural residues, energy crops, and synthetic compositions simulating post-material recovery facility (post-MRF) municipal solid waste continued to be investigated to elucidate conversion kinetics and basic energy-related properties. Changes in the thermal characteristics due to solid-liquid extraction using different solvents were also evaluated. Thermogravimetric/differential thermal analysis (TG/DTA) data obtained on common wood and agricultural feedstocks in California (fir, rice straw, wheat straw) under pyrolysis are distinctly correlated with structural compositions of the crude biomass. Kinetics shifts occur when feedstock is leached in water due to resulting compositional changes in alkali metals and potentially organic material. Ash fusion temperatures were also observed to increase following water-based extractions, increasing initial deformation temperatures by up to several hundred Kelvin for high ash, high alkali feedstocks. TG/DTA on a saline-irrigated energy crop (Jose Tall Wheatgrass) from the San Joaquin Valley of California revealed substantial differences in rates of reaction compared with other feedstocks due to high concentrations of salts in the biomass. The carbohydrate composition of the algal cell wall was investigated for its role in cell flocculation. Cultures of Chlorella variabilis NC64A, which were found to have different levels of neutral sugar, uronic acid and amino sugar in the cell wall when cultured in different nitrogen sources and concentrations, were subjected to flocculation with chitosan at dosages of 0 – 69.6 mg/L and pH values of 5.5, 7 and 8.5. In addition, flocculations of another three strains of Chlorella, which have different levels of cell wall components, were tested. Flocculation improved for all strains at pH 8.5 suggesting that inter molecular forces such as hydrogen bonding might be more important than charge neutralization in the flocculation of Chlorella. Total carbohydrate content in the cell wall was the most significant factor positively affecting the flocculation efficiency of Chlorella variabilis NC64A cells with different cell wall compositions and the other Chlorella strains. The results presented in this study suggest that chitosan flocculation can be improved by optimizing the cultural conditions to achieve higher cell wall polysaccharide content or selecting an algal strain with higher cell wall polysaccharide content. (WI) A project was initiated seeks to provide answers for fuel characteristics that offer the best environmental and economic efficiencies for biomass boilers for heat and power. Thirty samples representing Wisconsin based biomass were collected and chemically characterized for potential operational and regulatory issues when used in thermal processes. The project was used to help guide feedstock specifications for several bioenergy thermal projects. The physical and chemical properties of the biomass feedstocks harvest ed at Wisconsin are characterized. Parameters we quantify include particle-size distribution, chemical constituents (ADF, NDF, lingnin, ash, CP, WSC) and fermentation products.

Task 2: Develop and evaluate harvest, process and handling methods.

(TN) The University of Tennessee, DOE Oak Ridge National Lab, DOE Idaho National Laboratory and equipment manufacturers are collaborating to comprehensively investigate switchgrass supply from harvest through pre-processing. Experiments address issues with harvesting high yield grass crops, *in-bulk* densification, and quality metrics of supply. Emphasis addresses use of bales and bulk supply. As a part of the DOE High Tonnage grant, The University of Tennessee, Genera Energy, and Marathon Equipment Co. performed an alpha test of bulk compaction using commercial waste transfer technology. Since, switchgrass round bales require labor-intensive unit handling and de-baling processes that are not readily scalable, a bulk-chopped format was investigated to improve handling efficiencies throughout the harvest, transportation, and storage systems. However, low loose-filled bulk density of chopped switchgrass presented challenges for long distance transportation to the end user. Increasing biomass bulk density with minimal time and energy inputs was achieved using waste transfer equipment. A commercial-grade compactor with a ram face pressure of 347 kPa was used to compress size-reduced switchgrass into a 57 m^3 reinforced, ejector-style transfer trailer. The ejector trailer had a stand-alone, self-unloading feature. Results indicated in-bulk compaction as a promising method to improve transportation efficiencies of loose chopped biomass. It increased low bulk densities of low-moisture switchgrass feedstock by a factor of about 2x. Progress was made on the design of the entire bulk handling and storage system through partnerships with Laidig Systems and Kice Industries. Laidig has expertise with bulk reclaimer systems from storage, and Kice has expertise with bulk conveyance and dust control. MT continues to participate in the DOE/Sun Grant Regional Biomass Feedstock Partnership project. The major work includes 1) assessing the yield potential of existing CRP fields at different climate and geographic regions; 2) evaluating if fertilizer application will affect biomass yield and quality; 3) evaluating effect of harvest timing on biomass yield and quality. (MT) Currently, there are over 33 million acres of land enrolled in the CRP in the United States, of which 3 million acres are located in Montana. Although CRP lands are fragile and sensitive to environment, they could provide significant biomass production if they are managed appropriately by taking consideration of environmental quality and wildlife habitat. Current harvesting method is swathing and baling -- the method is popularly used by farmers. In this project, the CRP biomass is harvested at two growing stages, i.e. at peak biomass production and at frost kill. The project involves University of Illinois, Kansas State University, University of Missouri, North Dakota State University, South Dakota State University, University of Georgia, and Montana State University. MT is also working on genetic modification on camelina and selecting mutants to improve yield, oil profile, and reduce glucosinolate content in the meal. Another group at MSU Chemical and Biological Engineering Department is working on algae and thermal tolerant microorganisms for biofuel production. (TX) Drs. Searcy, Munster and Thomasson continue to spearhead research on biomass logistics, harvest and transport studies such as the following: (a) development of machine systems for biomass harvest and processing, (b) evaluate biomass characteristics during transport and storage, (c) evaluate energy expenditures associated with chopping, grinding and baling processes and (d) developing biomass modules to improve densities before shipment to bio-refineries. (TX) Dr. Munster studies include GIS analysis and logistics of mobile fast pyrolysis system in Texas and the North Central Region of the US. Dr. Lacey is investigating the use of raceways for algae production and developing appropriate control systems. Dr. Fernando is developing new alternative ways to extract oil from micro-algae. (ND) Particle size and particle size distribution (PSD) analysis are essential measures to evaluate the performance of machines (e.g., size reduction or densification) as well as the quality of biomass processed through these machines. We developed a novel, cost effective, accurate, and rapid machine vision method of measuring biomass particle size and analyzing their PSD. The developed □Volume approach use volume as the weighting factor and groups the particles based on their distinct lengths. The results coincide with standard mechanical sieving after length transformation. Our research brought out the lacunae of employing the mechanical sieving, and demonstrated a “falling through effect” of materials passing through the sieves and getting misclassified. (KY) • Large (2.44m x 1.52 m x 0.91 m) rectangular bale bulk densities range from 140-175 kg/m3, however a prototype of a baler innovation has increased bale bulk density to 190 kg/m3. The prototype was developed in collaboration with CNH, a manufacturer of agricultural equipment. (MS) Research started with a comparison of 10 grass species. Superimposed on the species comparison were harvest regimes in 30-day increments. From this study it was apparent that either two or one harvest per growing season would be required, with one harvest (an end of season harvest) better from a sustainable standpoint than two. Of the 10 species tested, highest yields were obtained from giant miscanthus cv. Freedom, switchgrass cv Alamo, napiergrass and sorghum sudangrass, however, the later two had harvest moistures of 30-38% (12% required for hay baling). Weathering of standing stalks of these species indicated that giant miscanthus and switchgrass would loose 15% of yield in 30 days, while the tropicals (sorghum and napiergrass) lost up to 45% yield in the same 30 day period. Post-frost harvest of giant miscanthus and switchgrass were lower in total ash (4%) and much lower in potassium, calcium and sulfur than sorghum and napiergrass (8%). Data from the weathering study indicated post-frost harvested giant miscanthus and switchgrass were initially lower in potassium than sorghum and napiergrass were after four months of weathering. A direct comparison of switchgrass and giant miscanthus indicated that yield during the first two years of establishment were similar for the two, but by year three giant miscanthus yielded more than switchgrass. Yield of both species is affected by drought, but previous harvest regime magnifies the affect. For both species, those plots previously harvested twice a year had half the yield of the respective plots (of the same species) only harvested once a year. Sequential planting of switchgrass, cv Alamo, indicated optimal planting date (as indicated by subsequent yield) was the first week of April, and NOT early May, as is found in Mississippi grower’s guidelines. Switchgrass can successfully be established under a nurse crop of sorghum sudangrass as long as the density of the sudangrass is less than 3 plants per linear foot of row. Population dynamics of switchgrass established as a spring monoculture indicated that under our conditions, there were 1.23 million seedlings/acre by the end of the planting season. Spring counts the following year were 80,000 plants/acre. Equilibrium was reached in the third year at 15,000 plants/acre, which coincides with peak yield. Winter hardy legumes were utilized to determine if they could replace nitrogen requirements in switchgrass. White and crimson clover established well in the test, arrowleaf and ball did not. Yield data indicated that either white or crimson could replace roughly 75 lbs/acre of nitrogen. (NY) Harvest management of switchgrass was evaluated in two fields on a high elevation marginal soil site. Harvest management included an October mowing and baling treatment and an October mowing with a windrowed swath overwintered in the field. A spring mowing/baling treatment also was included. Over two seasons, the highest yield was from the Fall mowed-Fall baled treatment at 7700 kg/ha of dry matter. Spring mowed-Spring baled grass averaged 37% lower yielding, and Fall windrowed-Spring baled averaged 32% lower yielding, compared to the Fall mowed-Fall baled yield mean over two seasons. An exceptionally wet spring in 2011 resulted in delayed baling until May. This had no impact on switchgrass left standing overwinter, but reduced yield of Fall-windrowed-Spring baled grass significantly, compared to the previous year. In general, the Fall mowed-Fall baled biomass was lower in fiber and lignin, but higher in elemental composition compared to all other treatments. The Spring mowed-Spring baled treatment was in general higher in fiber and lignin, and lower in elemental composition compared to other treatments. Fall mowed-Fall baled biomass was over 6-fold higher in K content compared to Spring mowed-Spring baled biomass. There were no differences in gross energy content among the mowing treatments, but Cl in Spring mowed-Spring baled grass dropped to 0.1 g/kg due to overwinter leaching. Field surface terrain, mowing season and baling season all impacted both yield and composition of switchgrass. (CA) Research on large-scale storage of four food processing wastes -- fresh grape pomace (FrGP), fermented grape pomace (FeGP), sugar beet pulp (SBP), and tomato pomace (TP) – was completed. The storage volume of 1200-L was used. The results suggested each feedstock requires unique storage strategies. Ethanol, whether present from yeast fermentation or as process residue, was effective in protecting FrGP and FeGP from spoiling. Ethanol could be recovered from FrGP and FeGP either before or after storage. Airtight storage of SBP was required to preserve anaerobic conditions and prevent aerobic mold contamination. Outputs included data on best management practices for storage of wet feedstocks. (WI) Wisconsin has done extensive research work on systems to harvest, process, handle, and store biomass feedstocks. The primary feedstocks we work with are corn stover, sorghum and perennial grasses (switchgrass and reed canarygrass). Our work has concentrated on single-pass corn stover harvest, two-pass corn stover harvest and harvest and storage of "moist" biomass feedstocks (i.e., 30 – 50% (w.b.) moisture) using anaerobic storage and preservation by fermentation. We have recently conducted on aerobic and anaerobic storage characteristics and aerobic stability of these materials (ASABE Paper No. 111082). (SD) Project has developed AFEX-pretreated feedstock billets from the three feedstocks. Physical properties such as bulk density, true density, porosity, water adsorption and solubility indices, moisture content, angle of repose, durability, compressibility, and thermal properties were evaluated for control, AFEX and PAKs made from different particle sizes (2, 4, and 8 mm). Low value of moisture content and thermal properties and high density and durability indicates that PAKs can be better for transportation and handling which reduces the transportation cost. Storage stability trials are currently underway. Trials to evaluate the conversion efficiency of raw, pretreated, compacted, and stored samples are also currently underway.

Task 3: Model and analyze integrated feedstock supply and process systems.
The previously-described bale cost system (engineering cost analysis) was refined, and new efforts are towards monitoring the bulk supply system in order to develop an engineering bulk cost model. (ND) Infield biomass round bales aggregation and transport to field stack was studied through a developed computer program based on Euclidean distances of operations. The various scenarios involving loading and bale transporting wagons and aggregating (e.g., direct single bale transport (control), central grouping, sub-grouping, parallel run, advanced bale picker) were analyzed. The program simulates bale locations as a function of crop, land area, and land geometry and evaluates the total distances of all considered scenarios and reports cumulative distances and percent change with respect to the control. Overall, the results indicate that increased number of bales transported per trip offers advantage to certain extent, and increase in area offered only a slight advantage over the control. The best method of collection is the advance bale picker producing >80% distance reduction from control. Further analysis and inclusion of energy and economics of operation were in progress. (NY) The goal of this project was the analysis of uncertainty associated with biofuel production. A simulation framework was developed to assess the impact of parametric uncertainties on material input requirements. A case study was conducted using a switchgrass to ethanol platform to determine the impact of uncertainty in feedstock yield, storage losses, sugar yield and fermentation yield. Results indicate that the most significant impact in input requirements arises from uncertainty in feedstock yield, followed by sugar yields. Storage losses and fermentation yields have less significant impacts on the process. These findings are important in determining the most effective areas for process improvements. Impacts on economics and energy inputs are also of particular interest and the simulation framework is currently being updated to allow assessment of these important resources. (CA) Comprehensive systems modeling continued with further development of the national scale Geospatial Bioenergy Systems Model (GBSM). This model was used in assessing optimal future biorefinery system development for the U.S. using coupled linear optimization and geographic information system (GIS) models with resource, infrastructure, and multiple conversion facility technoeconomic data. Scenario analysis using GBSM geospatial modeling of potential biomass resources and optimal biofuel production in the U.S. suggests that the federal RFS2 mandate for 2017 could be met at a nominal cost of $2.50 per gallon of gasoline equivalent at the fuel terminal, and about $3.00/gge for the 2022 standard. Assessments of feedstock availability also indicate

substantial differences from other national studies in terms of total quantity available based on sustainability metrics and other factors. (WI) We have recently developed a comprehensive model used to predict the cost of corn stover from field to pretreatment (ASABE Paper No. 111130). The model estimates costs of harvest, handling, storage, transport and processing corn stover harvested using eight different single-, two-, and three-pass harvesting schemes. A project was initiated seeks to provide answers for fuel characteristics that offer the best environmental and economic efficiencies for biomass boilers for heat and power. The research created a lab apparatus able to densify pellets in a lab environment and test their physical properties. Additionally an energy and material model was created based on the pellet production process at the Wood Residual Solutions plant in Montello, WI. The model calculates the cost and energy required to produce solid fuel pellets as compared to wood chips.

Objective B. Improve biofuel production processes.
B.1. Biological conversion processes
Task 1: Develop pretreatment methods for biological conversion processes
(OH) We have studied the concurrent wet storage and microbial/alkali pretreatment of lignocellulosic biomass for biofuel production. Corn stover could be successfully pretreated with Ceriporiopsis subvermispora with cellulose lost than 5% and lignin degradation as much as 40%. The overall glucose yield reached about 70%. (KS) Three acid-functionalized nanoparticles were synthesized for pretreatment and hydrolysis of lignocellulosic biomass. Silica-protected cobalt spinel ferrite nanoparticles were functionalized with perfluoroalkylsulfonic acid (PFS), alkylsulfonic acid (AS), and butylcarboxylic acid (BCOOH) groups. These nanoparticles were magnetically separated from the reaction media and reused. The average diameter was 2 nm for both PFS and BCOOH nanoparticles and 7 nm for AS nanoparticles. FTIR confirmed the presence of sulfonic and carboxylic acid functional groups. Cellobiose hydrolysis was used as a model reaction to evaluate the performance of acid-functionalized magnetic nanoparticles for breaking β-(1→4) glycosidic bonds. Cellobiose conversion of 78% was achieved when using AS nanoparticles as the catalyst at 175°C for 1 h, which was significantly higher than the conversion for the control experiment (52%). AS nanoparticles retained more than 60% of their sulfonic acids groups after the first run, and 65% and 60% conversion were obtained for the second and third runs, respectively. (NY) In 2010-2011 we have published a detailed description of the RNAi procedure in protoplasts in Jung et al, 2011, Methods Mol Biol (below), and proceeded with Objective 2. We focused on testing whether RNAi silencing of the known components of the cell wall biogenesis machinery will alter the ability of protoplasts to regenerate their cell walls. We used Arabidopsis thaliana for the proof-of-concept since the molecular identity of components of the cell wall biogenesis machinery is better defined in this model system. Isolated Arabidopsis protoplasts were transfected with double stranded RNA (dsRNA) against a gene encoding A. thaliana cellulose synthase 1 (CesA1). Transfected protoplasts were transferred into protoplast regeneration medium after 24 h of transfection. Cell wall regeneration was analyzed by staining protoplasts with calcofluor white (CFW) that bind to β1-3and β 1-4 polysaccharides such as β[1→4] D-glucose found in cellulose. When excited with ultraviolet radiation, CFW bound to cellulose fluoresce with an intense bluish/white color. On the onset of this study, we developed a procedure for staining intact cells with CFW. We ensured that fluorescence of CFW derived solely from binding to the periphery-located cellulose microfibrils in intact Arabidopsis cells. As we expected, CFW-mediated fluorescence was not found on the periphery of protoplasts that were transfected with water (controls) and were incubated in the protoplasts-specific medium (W5). In contrast, 76% of control protoplasts incorporated CFW on the protoplasts' periphery after incubation in regeneration medium. This suggested that formation of β(1→4) D-glucose polymers occurred on the protoplasts' periphery. Only 50% of RNAi protoplasts were stained with CFW after incubation in regeneration medium, suggesting that RNAi against CesA1 decreased their ability to synthesize β(1→4) D-glucose polymers in comparison with control protoplasts. The major obstacle in

this procedure, however, was the viability of Arabidopsis protoplasts in regeneration medium: it decreased by 50%. However, since RNAi against CesA1 led to the decrease in the ability of protoplast to produce cellulose, and since our goal is to use Brachypodium, we will now work on modifying the regeneration medium as appropriate to Brachypodium protoplasts. We will develop this procedure in the year 3. (CA) Studies were completed to examine the pretreatment of sugar beet pulp (SBP) by acid pretreatment. Dilute acid pretreatment was selected for pretreatment of SBP. Three critical parameters including temperature (120–160˚C), acid concentration (0-1 wt%) and solid loading (2-6 wt%) were tested. The pretreatment time was set at 5 min. Results demonstrated that the dilute acid pretreatment significantly improved the digestibility of SBP to achieve high sugar and ethanol yield upon hydrolysis and fermentation. The results have been disseminated to communities of interest including Novozymes (Davis, CA) and Chevron Technologies Ventures. Alkaline pretreatment of straw, grape pomace and woody biomass for increasing the biodegradability was investigated. New pretreatment processes using sodium hydroxide (NaOH) was developed. New methods for chemical and lignin separation and recovery were also developed. Using NaOH for pretreatment at ambient temperature (20˚C) was shown to be very effective in increasing the biogas yield via anaerobic digestion and sugar yield via enzyme hydrolysis from rice straw and grape pomace. The chemical requirement varies with different materials due to different lignin contents. For grape pomace and rice straw, recommended chemical loading was 0.02 and 0.10 gNaOH per g of dry biomass (10%) for 24 hour treatment with corresponding methane yields of 362 and 317 ml/gVS. For woody biomass from orchards, pretreatment at a higher temperature was needed. After 1 hour pretreatment with 10% NaOH loading and at 120˚C, methane yield of woody biomass was 213 ml/gVS. Separation of lignin in black liquor after the biomass pretreatment would enable recovery of lignin for industrial or energy uses and also improve the quality of water for later reuse in the pretreatment process. Two step alkaline pretreatment was found to be better than single step process. More research is underway to optimize the conditions for the two step process. The research outputs include new process design and optimized conditions for achieving effective biomass pretreatment. The new biomass pretreatment technologies can be applied to bioconversion systems, including anaerobic digestion and ethanol fermentation. (AR) *Populus deltoides* clones S13C20 and S7C15, used in this study originated from Eastern Texas, and were cultivated for 14 years in Pine Tree, AR. Specifically, *P. deltoides* clones S13C20 and S7C15 had specific gravities of 0.48 and 0.40, respectively. Martin et al. (2011) reported on the xylose recoveries of heartwood from *P. deltoides* clones S13C20 and S7C15 during dilute acid pretreatment, indicating that clone S7C15 pretreated at 140ºC 1% H_2SO_4 yielded the highest average xylose recovery of 56%. Although pretreatment is a critical step, total sugar release will only be obtained by combining pretreatment to enzymatic hydrolysis. Results (not shown) showed that, of the range of temperatures tested between 140°C to 180°C using 1% H_2SO_4, the pretreatment temperature of 160°C was optimum for coupling pretreatment to enzymatic hydrolysis. Glucose recovery from heartwood from both clones (S13C20, high specific gravity and S7C15 low specific gravity) pretreated in 1% H_2SO_4 at 160ºC and enzymatically saccharified was 60%. Monomeric sugar recovery was based on dry weight (average moisture content of high wood was 16%, with low wood being 20%). Data analysis of wood samples showed that glucose recovery from the low specific gravity wood was significantly higher than that from the high specific gravity wood. Sweetgum heartwood was ground to 20 mesh and soaked in 1% sulfuric acid at a 1:10 ratio, overnight before pretreatment. The maximum xylose yields of 99% were obtained at 140˚C for 60 min. The maximum glucose value of 70% was obtained by coupling pretreatment at 160˚C for 60 min with enzymatic hydrolysis. The formation of furfural acetic acid and formic acid was also monitored. Temperature had an effect on the yields of furfural, formic acid, and acetic acid. Furfural yields at 160˚C were almost three times higher than those at 140˚C for all the time treatments considered in this study. Furfural yields were less than 0.01 mg/mg-biomass at 140˚C and 0.03 mg/mg-biomass 160˚C. The maximum furfural concentrations occurred at 160˚C for 60 min, which were also the pretreatment conditions for maximum glucose and total sugar yield. Trade-offs between maximum carbohydrate yields and production of inhibitory compounds need to be determined. (WI) Our research activities in this area have concentrated on pretreatment during storage at ambient temperature and pressure but for extended duration. This work has looked at physical, chemical, and biological amendments to pretreat during anaerobic storage.

Task 2: Develop conversion processes
(OK) Efforts to further develop fermentation of syngas to produce ethanol are ongoing. We have recently completed a study on monitoring gene expression and enzyme activities for Carbon monoxide dehydrogenase, ethanol dehydrogenase and butanol dehydrogenase. Gene expression of the genes coding for these enzymes was highest while ethanol was produced, but the enzyme activities were higher during cell growth and before solvents were produced. We also have developed a minimal medium for ethanol production from glucose using the thermotolerant yeast *Kluyveromyces marxianus* IMB3. This medium has slightly lower ethanol production rates than the complex medium we currently use, but the cost of the medium is much lower than the complex medium. (SD) One high yielding prairie cordgrass variety was released, and a second variety will be released in 2012. Yields are 8-10 tons/ac, compared to switchgrass at 4-5 tons/ac. Agronomic practices for stand establishment and maintenance have been determined, while DNA analysis is continuing, and will be used in breeding efforts. Extrusion pretreatment conditions (90ºC, 65 rpm, 20% wb, 8 mm) have been optimized, showing glucose, xylose and combined sugar recoveries of 48, 77 and 57%, respectively. High solids saccharification and fermentation processes have achieved solid loadings of 34% by weight, but low water activity reduced ethanol yields. Current trials are evaluating solids loadings of 20-27%. (HI) Our research mainly focuses on anaerobic digestion of green grass for biomethane production. The biomethane produced from green grass has been shown to offer better net energy return than the first generation liquid biofuels such as ethanol. These findings have resulted significant interest on grassland and other green grass as potential sources of renewable feedstocks for sustainable bioenergy production. (TX) Dr Engler has developed a modular anaerobic digestion system utilizing animal and other biorefinery wastes such as glycerin. An MS student has recently completed a thesis on the production of biogas from anaerobic digestion of glycerin. (KS) PS sorghum with high soluble sugar content (17% db) was used for this study. The objective of this research was to utilize both soluble sugars and biomass for ethanol product. The effect of diluted sulfuric acid pretreatment on enzymatic hydrolysis was investigated. The soluble sugars were washed out from biomass first and then combined with the sugars after enzymatic hydrolysis for ethanol fermentation. An 80% of glucose yield from sorghum biomass was achieved and the total ethanol yield is 74.5% (about 0.2 g ethanol from 1 g PS sorghum. In this study, various biomass sources, including wheat straw, switchgrass, miscanthus, bmr sorghum from two locations, and sorghum bagasse were evaluated for their sugar and ethanol yield. The primary purpose of this research was to evaluate the effect of biomass composition, particularly the lignin content, on product yield. To effectively remove lignin, mild alkali (2% w/v, 121oC for 30 minutes) pretreatment was adopted at high solid loading. The initial biomass composition of the samples was evaluated and the lignin content varied from 9.2 (for the bmr sorghum samples) to 18.4% w/v (wheat and sorghum bagasse). However, the final ethanol yield from wheat and sorghum bagasse at 4.2% w/v was found to be higher than the bmr sorghum and warm season grasses. This study suggested that the quality of lignin plays an important role on final titer of sugars and ethanol yield. In similar studies, the effect of drought and heat stress, and rice bran on ethanol yield were evaluated. (IL) Use of evaporators is a typical method to concentrate thin stillage before it is blended with wet grains and dried to make DDGS. Using process simulation, our research determined that a multistage microfiltration system could be optimized that would require lower capital and operating costs than conventional multieffect evaporation. In the conventional dry grind process, the entire kernel is ground and subjected to fermentation to produce

ethanol. The material left over from fermentation forms a single coproduct, DDGS. Wet and dry fractionation processes recover corn germ and fiber fractions prior to fermentation to diversify coproducts made in parallel with ethanol as well as increased revenues from these coproducts. In experiments using diverse corn endosperm characteristics, it was found that wet and dry fractionation methods recovered germ and fiber fractions that could be sold in addition to a post fermentation coproduct. Both fractionation processes resulted in higher final ethanol concentrations than conventional dry grind, due to higher fermentable substrate concentrations per batch. Using an experimental wet fractionation process to produce ethanol, the E-Mill process, phytase was added during an initial incubation period with starch hydrolyzing enzymes. In phytase treatments, cleaner separation of corn components resulted, as indicated by lower residual starch concentrations in germ and pericarp fractions. Also, higher final ethanol concentrations resulted. These results indicate that phytase use may increase coproduct values, due to higher oil and protein contents and increased ethanol production at corn ethanol facilities. Converting grain and biomass to ethanol uses significant amounts of water. For conventional corn ethanol, 3 to 4 gal water per gal ethanol are required typically. For biomass ethanol, it is projected that 6 to 10 gal water per gal ethanol will be required. Methods are needed that will reduce water requirements. A majority of the water requirements are for cooling tower operation. The feasibility of using cooling tower blow down water (cooling tower water normally removed to waste treatment) in corn grain fermentation was determined. Fermentations using blow down water resulted in similar final ethanol concentrations and residual glucose levels observed with fermentations using deionized water. A fungal protease was used to generate free amino nitrogen (FAN) from corn endosperm and compared to conventional urea addition. When fermenting dry fractionated endosperm substrate, fermentations with protease generated FAN increased fermentation times and decreased fermentation times compared to urea supplemented fermentations. Incubation with protease did not affect subsequent liquefaction and saccharification characteristics. Protease generated FAN may improve economics of dry fractionation processes and reduce use of urea. KY designed and constructed a solid state cultivation (SSC) reactor system with automated media replacement (liquid phase only) based on time and reactor media pH, in order to compare no pH control in the reactor and controlled pH by media placement every twelve hours; and compare SSC when the pH is controlled by media replacement every 12 hours compared to pH controlled by media replacement whenever the media pH dropped below a set threshold. (CA) Raw and ensiled grape pomace underwent simultaneous saccharification and fermentation (SSF) using Escherichia coli KO11. Outputs from the research included hydrolysis and fermentation approaches for conversion of grape pomace to ethanol. Enzyme production research was conducted to produce cellulase enzymes using Trichoderma reesei on various lignocellulosic substrates, including rice straw, grape pomace and pure celloluse. The results indicated that alkaline pretreated rice straw was a better substrate for cellulase production as compared to raw rice straw and pure cellulose. The activity of cellulase produced from rice straw was higher than the commercial cellulase tested. More research is underway to optimize the conditions for enzyme production. Anaerobic digestion of various organic residues, including poultry manure, vegetable waste, sugar beet pulp and leaves were investigated for the purpose of developing effective biogas production system from these biomass materials. Both batch and continuous digesters were tested and recommendations were developed for the optimum conditions for designing and operating anaerobic digesters. The results of anaerobic digestion research led to improved designs of anaerobic digester system for treatment of vegetable waste and an invention of three-stage high rate anaerobic digestion system (HRD). An alternative two step method for conversion of cellulose biomass into biofuels was investigated. Cellulose was converted to cellobionate by a genetically modified fungus without exiguous cellulase addition in an aerobic fermentation step. Cellobionate was then converted to fuels and chemicals in a second anaerobic step. The cellobionate was produced by the recombinant N. crassa and production conditions were optimized. The fermentation of hydrolysate of cellobionate to ethanol was achieved using E coli KO11. The results have demonstrated the preliminary viability of the proposed new route for biofuels production from cellulosic biomass. The new approach can potentially lower the cost of cellulosic biomass bioprocessing drastically. Future work will be focused on optimization of the cellobionate production from cellulose and the optimization of the fermentation process for ethanol production from cellobionate. Research results have been presented at scientific meetings, in research reports and articles.

Task 3: Develop value-added products from hemicellulose and lignin
Our research group has been working on fungal protein production on hemicellulose-derived sugar supplemented with front-end derived Napier juice. Our study showed prolific fungal growth on sugars, especially pentoses that are not easily metabolized to biofuel by microbes. The fungal biomass yield as high as 10 g biomass/g biomass added. The fungal protein can be processed into animal feeds.

B.2. Thermochemical conversion processes
Task 1: Develop pretreatment methods

Task 2: Develop conversion processes
(HI) Khanal's research group is working on syngas fermentation to biofuel. Our research activity focuses on mass transfer of syngas components in the aqueous phase using composite hallow fiber membrane. Our study showed that use of membrane could improve the CO dissolution by nearly 5-10 folds compared to stirred-tank reactor. (TX) Dr. Capareda has completed the development of the new TAMU mobile fluidized bed gasification system for heat and power generation. The technology was licensed by SDL Citadel Global, a start-up company based in Dallas, Texas and they have entered into a short sponsored research agreement with TAMU for commercialization. (OK) Improved Downdraft Gasifier Performance by Preheating Input Air: Air gasification study on low bulk density biomass materials was conducted utilizing an exploratory downdraft gasifier system. Preheating the gasifying air is one of the methods to enhance performance of the gasifier system. Switchgrass gasification was evaluated at two levels of input air preheating temperatures: 31-34°C and 200°C. The experimental results showed that the pyrolysis zone temperature increased to 160°C consequently the tar content decreased from 16.7 g/Nm3 to 12.5 g/Nm3 as the input air preheating temperature increased from 31-34°C to 200°C. The other performance parameters such as producer gas compositions, heating values, yield, hot and cold gas efficiencies did not change significantly. 2. Performance evaluation of a new laboratory-scale fluidized-bed biomass gasifier (FBBG):
The goal of the present study was to evaluate performance of a 2 – 5 kg h-1 laboratory scale fluidized bed biomass gasifier (FBBG) using switchgrass as a biomass feedstock. The main components of the FBBG system were a biomass feeding unit, a fluidized bed gasifier, an air supply unit with preheater, an air pressure regulator, two cyclone separators, an orifice plate and a jet-type self-aerated producer gas burner. Silica sand was used as the reactor bed material. Experiments were conducted to evaluate the effect of equivalence ratio (ER) on the reactor temperature profile, energy efficiencies, and producer gas yield and quality such as gas composition and particulate contents. The ER of 0.32 was found to be optimal with producer gas higher heating value of 6.17 MJ Nm-3 and tar and particulates contents of 4.28 g Nm-3 and 0.13 g Nm-3, respectively. The cold and hot gas efficiencies at the optimal conditions were 81% and 84%, respectively, while these efficiencies decreased on either side of the optimal value of ER. Both gas yield and carbon conversion efficiencies were found to be in positive correlation to ER with maximum values (gas yield: 3.23 Nm3 kg-1 of biomass (d.b.); carbon conversion efficiency: 96%) at an ER of 0.51. 3. Characterization of switchgrass using TGA-FTIR under nitrogen and air atmospheres:
The overall goal of this project is to predict gasification characteristics of biomass based on its biochemical composition. Thermochemical conversion is one of the efficient ways of converting biomass

into energy and fuels. Understanding reaction kinetics and the nature of volatiles evolving is essential to optimize thermochemical processes. To accomplish this, thermogravimetric analyzer (TGA) coupled with Fourier Transform Infrared Spectrometer (FTIR) was used. Decomposition of switchgrass was found to occur in three stages. Significant weight loss occurred in the temperature range of 220 to 420 °C in nitrogen atmosphere and 220 to 390 °C in air atmosphere depending on heating rate. Weight loss kinetics of switchgrass, cellulose, hemicellulose and lignin were evaluated under inert and non-inert conditions. CO_2, CO, CH_4 plus some hydrocarbons were identified as major volatiles evolved during switchgrass decomposition. 4. Investigations on Acetone-Water based Biomass Producer gas Wet Scrubbing: Objectives were to (i) design and development of a laboratory-scale exploratory test facility for biomass Producer gas wet scrubbing research, and (ii) investigating the effects of acetone concentration levels in the mixtures with water on biomass producer gas wet scrubbing. Preliminary experiments conducted, so far with Acetone-water solvents having acetone concentration levels of 20, 40, and 60 %, showed clean producer gas and undetectable tar content in the clean producer gas. Only with the Acetone-to-water solvent ratio of 60:40, traces of acetone were observed in the clean producer gas solvent. Average ΔP across wet scrubbing system was 3.3-inch of water column. (KS) The performance of a selective Ni-based catalyst in biomass gasification tar removal and syngas reforming was studied. Benzene was used as the model tar to optimize catalytic reaction conditions. Parameters investigated were reaction temperature (700ºC to 900ºC), gas residence time (0.1 to 1.1 s), and catalyst loadings (3% to 21% of the weight of γ-Al_2O_3 support). On the basis of the benzene test, a reaction temperature of 800ºC, catalyst loading of 15wt%, and residence time of 0.3 s were chosen as optimum reaction conditions. Testing of these conditions showed that the Ni/γ-Al_2O_3 catalyst removed more than 99% of tars in syngas in the downdraft gasifier and 98% in the updraft gasifier. Concentrations of combustible compounds of syngas also increased significantly.
Biomass composition has a significant on lignocellulosic biomass hydrothermal conversion (HTC). For cellulose HTC (20 min, 10% cellulose), bio-oil yield (based on biomass weight) increased from 19.84% to 21.36% as reaction temperature increased from 260°C to 300°C, and then decreased to 18.96% as temperature further increased to 340°C. Bio-oil yields of lignin HTC at 300°C and 360°C were 3.9% and 5.22%, respectively. The highest bio-oil yield of 23.9% from corn cobs HTC was obtained at 305�C, 20 min retention time, and 10% biomass content. (MN) UMN is developing two biomass conversion processes, namely microwave assisted pyrolysis (MAP) and hydrothermal liquefaction (HTL). A stationary pilot MAP system and a mobile pilot MAP system were constructed. The stationary MAP system has been tested and demonstrated. The mobile MAP system will be operational soon. Our objective is to develop conversion technologies that facilitate distributed conversion concept. A continuous small pilot scale HTL system was constructed and tested. A new HTL system based on the experience obtained with the current system has been designed and is being constructed. HTL process is ideal for converting wet biomass such as algae, sludge, animal wastes, food processing wastes, etc. The use of catalysts to improve conversion yields and product quality and stability was investigated. Some catalysts were found to significantly improve the reaction selectivity and chemical profiles of the conversion products. New catalytic processes were developed to upgrade the intermediates produced from the conversion processes to gasoline like liquid fuels. Non-thermal plasma (NTP) assisted catalytic gas reforming processes were investigated. The objective is to reform syngas from biomass gasification and pyrolysis to ammonia and hydrocarbons. (CA) Torrefaction studies were conducted in order to assess energy and mass yields and quality changes in feedstock for thermochemical applications. Solid product mass yields for torrefied post-MRF MSW were above 78% with energy yields above 96% for temperatures below 300°C. At 350°C, above the typical torrefaction temperature regime, mass yield declined to 65% while energy yield dropped to 93%.

Task 3: Improve methods for characterization of intermediate products and process control.

(TX) Dr. Thomasson is investigating the use of spectral devices (e.g. NIR) for biomass characterization and biomass yield estimation. Several invention disclosures have been filed with the Office of Technology and Commercialization of TAMU. (MS) Novel heterogeneous catalytic systems were evaluated and tested for production gasoline range fuels from syngas. Since the nitrogen level of the biomass derived syngas can be up to 60 %, in the catalytic converting syngas to gasoline process, work has concentrated on the development of catalysts for the production liquid fuels from nitrogen-rich syngas. Previous work demonstrated that the Mo/HZSM-5 catalyst (the 2nd generation catalyst) was active in Fischer–Tropsch synthesis (FTS) when using syngas without nitrogen component. Mo/HZSM-5 catalyst was continued evaluated for FTS, but using high level nitrogen containing syngas. Liquid hydrocarbons formed on the Mo/HZSM-5 were composed mainly of alkyl-substituted aromatics and lower branched and cyclized alkanes. Lower hydrocarbons produced included mainly methane, ethane, propane and iso-butane. However, the CO conversion and selectivity of liquid hydrocarbons from biomass derived syngas were not satisfied when comparing to pure syngas (without nitrogen).

B.3. Biodiesel production processes

Task 1: Characterize new feedstocks
(MN) We are developing a suite of technologies to mass cultivate, harvest, and convert microalgae to liquid fuels. Microalgae are a non-lignin biomass feedstock from which lipids can be extracted and converted to biodiesel. We have successfully selected high performance heterotrophic algae strains that can grow rapidly in wastewaters such as concentrated municipal wastewater and animal wastewater, and contain high concentration of lipids. We have developed low capital cost, minimum maintenance, small footprints hybrid photobioreactors. Such production systems allow year around operation in almost anywhere. We are developing new harvest techniques including biodegradable flocculant and air flocculation processes. (HI) The University of Hawaii group is working on non-edible oil crop, Jatropha curcus L. for biodiesel production. The team is conducting several field trials on different Hawaiian Islands to examine the yield under different environmental conditions.

Task 2: Develop an understanding of fuel quality and performance issues
(ND) A cold soak filtration test (CSFT; ASTM D 7501-09b) was included in B100 specifications under ASTM D 6751-09, bringing new challenges to biodiesel producers and researchers investigating B100 quality. For a plant breeding program evaluating canola biodiesel quality traits, rapid assessment of biodiesel quality is important. Typically, a limited amount of seed from new canola lines is available; therefore, obtaining the required volume of biodiesel for evaluating cold soak filterability (300 mL) is not possible. In order to rapidly screen canola breeding lines for B100 quality, cold soak filterability must be assessed with reduced volumes of biodiesel. The primary objective of this study was to evaluate the impact of saturated monoglycerides, glycerin, and soap on cold soak filterability. Biodiesel filtration time rapidly escalated when the SMG concentration was above 0.28%. The influence of saturated monoglycerides (0.04% to 0.46% w/w) on biodiesel precipitate formation was also evaluated. A regression model was generated to predict the filterability of biodiesel against the concentrations of trace contaminants. The results will be instrumental to scaling down biodiesel CSFT for a canola breeding program. Canola biodiesel (fatty acid methyl esters, FAME) may have superior cold flow properties when compared to other biodiesel feedstocks, which is attributed to canola's high unsaturated and low saturated fat content. The objective of this study was to evaluate canola biodiesel fatty acid composition, cloud point (CP) and oil stability index (OSI) among several ND locations and production years. In Experiment 1, bulked canola varieties from seven growing seasons (2003–2009) were analyzed and in Experiment 2 a single canola variety (Interstate Hyola 357RR) harvested at two locations (2003–2005, and 2007) were analyzed. FAME was produced directly from seed via in situ

alkaline transesterification methods. CP ranged from -0.1 to -2.4 _C and was significantly impacted by year and location. FAME generally met the ASTM B100 specification for OSI (3 h), but increased seed storage decreased stability. No significant differences were detected in FAME composition, and iodine value ranged from 108 to 123 g I2/100 g. A significant relationship between fat saturation and location with CP and stability was not detected among the samples in this study. Variation in fatty acid composition was small; thus, the significant variability in CP and OSI suggests either differences in minor constituents (antioxidants, waxes) or environmental seed stress impacted biodiesel quality. Our study supports the value of examining biodiesel quality in a canola breeding program.

Task 3: Develop and characterize innovative processes for biodiesel production
(MN) We are investigating direct in situ transesterification of harvested algal biomass to produce biodiesel without extracting the oil from algal biomass. We have tested direct microwave assisted pyrolysis of harvested algal biomass to biofuels which can be directly blended with other commercial liquid fuels.

Task 4: Utilize coproducts
(HI) In this research, my research team is converting low-value co-product, crude glycerol into value-added co-products using edible fungi. The protein-rich fungal biomass forms pellet due to self-agglomeration and could be easily recovered through gravity settling. The recovered fungal biomass is rich in protein-rich that can be mixed with commercial fishmeal at different percents, which would reduce the import of expensive fish meal and it may potentially improve the fish and shrimp productivity and quality. Jatropha seedcake, a residue from Jatropha biodiesel production, contains high amount of protein and essential amino acids. Thus, the use of Jatropha-derived seedcake as a protein source for aquatic feed applications is a desirable option to replace the use of commercial aquatic feeds e.g. fishmeal and soybean meal. The protein-rich seedcake, however, contains toxic compounds, including phorbol esters and curcin, which makes it unsuitable for aquatic feed applications. Our research team is investigating an innovative fungal technology as a cost effective and environment-friendly method for detoxifying Jatropha seedcake. Fungi, Rhizopus oligosporus and Phanerochate chrysosporium are being examined in this study in solid-state fermentation. (OH) We have developed a liquefaction process (patent awarded) to produce biopolyols and polyurethane foam from crude glycerin (biodiesel byproduct) and lignocellulosic biomass. This project is funded by the Ohio Soybean Council and has been licensed to Polygreen Technologies LLC for commercial production. We are working with Polygreen Technologies, HFI, LLC, Ford Motors Company, Honda North America, and Green Insulation Technologies, LLC for pilot scale demonstration now. (TX) Glycerol glut as a consequence of rapid growth of biodiesel industry has attracted extensive research worldwide for the valorization of crude glycerol. Acrolein currently manufactured via the oxidation of petroleum-based propylene is one of those glycerol derivatives that hold an important status as intermediate for the production of many high-value chemicals, such as acrylic acid, methionine, polyester resin, superabsorbents, and polyurethane. However, processing technologies that directly use industrial crude glycerol for acrolein production remain unexplored. High-purity glycerol refined from industrial crude glycerol will lead to prohibitively high energy consumption and high cost. Thus, a sustainable and cost-effective process development for acrolein production from crude glycerol is highly desirable. We have developed a method using subcritical water technology that makes it possible to directly use crude glycerol as feedstock for acrolein production. The invention encompasses steps of oil-water separation, inline salt removal, dehydration in subcritical water, heat exchange/recycle, and water/catalyst reuse. Acrolein yield higher than 85 mol% from crude glycerol has been demonstrated. In addition to acrolein, main impurities in crude glycerol such as free fatty acids and salts can be effectively recovered as byproducts with additional commercial value.

Objective C. Identify, develop and evaluate sustainable processes to convert biomass resources into biochemicals, biocatalysts and biomaterials.

Task 1: Discover and characterize biochemicals, biocatalysts, and biomaterials in biomass.
(ND) Vegetable oils are a renewable source for the production of oleochemicals. Oils with high-oleic and low saturate content may be an excellent source for producing epoxy resins, because of the uniform distribution of cross-linking sites. Bio-based epoxy resins can be used as matrix components for composite materials. Vegetable oils with oleic acid content varying from 22 to 86% were epoxidized in situ with peracetic acid and a heterogeneous catalyst. Contents of 30, 35, and 40% (% wt of total matrix) of bio-based epoxy resins were blended with a synthetic epoxy resin, and an anhydride curing agent to be applied as the matrix in the preparation of composites using E-glass as the structural fiber. A control was also prepared with a 100% synthetic epoxy resin. Mechanical properties (flexural properties, interlaminar shear strength, and dynamic mechanical analysis) of the produced composite materials were evaluated. More flexible but less resistant composites were obtained as the content of oleic acid in the initial vegetable oil and the content of bio-based resin increased. Toughness increased at lower levels of oleic acid content. Interlaminar shear strength showed low adhesion of the matrix-fiber at a bio-based epoxy resin content of 40%. High homogeneity and slightly reduced glass transition temperatures were shown in composites with high-oleic bio-based resins when compared with the control. The application of bio-based epoxy resins in the production of composites materials helps decrease the dependence on petroleum-based resins, and may lead to a high added-value product from vegetable oils. However, future studies are needed to increase the adhesion of matrices containing bio-based resin with synthetic and natural fibers, which will improve the mechanical performance of the composites. (TX) Research efforts were made for developing an integrated approach for converting lignocellulosic feedstocks into high value products of fiber, film, and composite. Studied converting technologies include bast fiber processing, bast fiber nonwoven and composite formation, and regenerated cellulose fiber and film spinning from cellulose solutions, and advanced instrumental methods for characterizing these biobased materials. Cellulose pulp from waste bagasse and wood was used for producing regenerated cellulose fiber and film by dissolving cellulose in an ionic liquid. Antimicrobial cellulose fiber and film products were produced with addition of nanoparticles. Regenerated cellulose fiber and film products were characterized by TEM and SEM techniques incorporated with computerized image analysis. Crystallinity and crystal size of regenerated fiber and film were measured using a method of Wide Angle X-ray Diffraction. Research data determined a relation between fiber drawing ratio and fiber tensile strength, influence of cellulose solution concentration on fiber crystallinity, crystal size, and crystal orientation. The antimicrobial performance of the cellulose/nanoparticle fiber and film was tested using the method ASTM E 2149-10 with E. coli, indicating a significant efficacy of killing 99.998% of E. coli within 3 hours of contact time. Kenaf fiber composite was produced using nonwoven and press molding technologies. Optimal condition for kenaf fiber composite fabrication was studied. The composite end use properties for auto interior applications in terms of mechanical strength, thermal stability, and acoustical property were evaluated. (WI) A project was initiated that investigated a process to convert woody biomass into levulinic and formic acid, which have been shown to be capable of being converted catalytically to jet fuel by others. The conversion yield to these products by acid treatments was optimized and more importantly, degradation products were minimized beyond previously reported results. The degradation products have been shown to hinder the catalytic reactions necessary for the subsequent conversion steps. (HI) The Li research group in Hawaii continues to search for bacteria as catalysts for biodegradation and biosynthesis. For example, we have isolated a novel bacterial species, Arthrobacter

sp. JS37, from oil contaminated soil. Arthrobacter sp. JS37 has shown very interesting physiological properties and substrate utilization spectra. The results showed that JS37 secrets lipase to cleave triglycerides into fatty acids and glycerin. JS37 preferably and efficiently utilizes glycerin as substrate and can tolerate up to 5% methanol. JS37 produces a large amount of polysaccharides at particular conditions such as 40 °C and pH 9.1 and use of glycerin as substrate (approximately 3 g of polysaccharides per gram of cell mass). Clean biodiesel fuel from triglycerides can be potentially produced in a one-pot process.

Task 2: Develop separation processes for biochemicals, biocatalysts, and biomaterials.

Task 3: Develop applications for biochemicals and biocatalysts with biological activity.
(HI) The Li team in Hawaii continues to biosensors and new analytical methodologies for measurement of biological activities in feedstock, food and the environment. In addition, we have worked on looking for alternative supplements to rear tephritid fruit flies for fruit fly control. For example, canola, corn, and vegetable oils have been recently found to be alternative supplements of the expensive wheat germ oil in fruit fly liquid larval diet. Wheat germ oil can be substituted with corn oil, vegetable oil, or canola oils for the melon fly Bactrocera cucurbitae, while corn oil is a better alternative for the oriental fruit fly B. dorsalis, and vegetable oil is the best for the Mediterranean fruit fly Ceratitis capitata.

Task 4: Develop enabling technologies for biochemical production.
(KS) Low-cost and high-performance soy flour adhesives were developed as alternatives partially replace urea formaldehyde-based adhesives for wood particle board. This technology is currently used and can replace about 0.5 billion lbs of urea formaldehyde-based adhesives. Soy protein based adhesives were derived from soybean flour. It uses water as solvent, and can be used for plywood products. 3) Soy protein based latex adhesives. This technology possesses wet-tacky property and can be cured at room temperature. This technology can replace some of the vinyl acetate-based latex adhesives with potential for labeling and packaging applications.
The goal of this research was to develop cost-effective protein based latex adhesives to replace or partially replace petroleum based adhesives for wood veneer applications. Soy protein latex adhesives were successfully developed for wood veneer uses, and are currently providing samples to facilitate industries for commercial evaluations. The newly developed soy protein based latex adhesives can be cured at either room temperature or elevated temperature and showed high wet adhesion strength. Soy protein based latex adhesives have a great potential to replace or partially replace petroleum-based adhesives for wood veneer, labeling, and other applications. The outcomes from this research will have significant impact on the green industry through the development and demonstration of novel, environmentally friendly technologies for use in adhesives, paints and coatings. The objective of this research was to develop a protein adhesive from low-cost sorghum DDGS. Three extraction methods were evaluated for sorghum protein extraction from DDG including acetic acid-extracted sorghum protein from DDGS (PI), aqueous ethanol-extracted sorghum protein from DDGS (PII) and acetic acid-extracted sorghum protein from sorghum flour (PF). PI had the best adhesion performance in terms of dry, wet and soak adhesion strength, followed by PF and PII. The wet strength of PI at a concentration of 12% protein assembled at 150 °C was 3.15 MPa, compared to 2.17 MPa and 2.59 MPa for PII and PF, respectively. The high percentage of hydrophobic amino acids in PI (57%) was likely a key factor in the increased water resistance of PI compared with soy protein (36% hydrophobic amino acids). These results indicated that sorghum protein has huge potential as an alternative to petroleum-based adhesives. Canola protein was extracted from canola meal through alkali solubilization and acid precipitation methods, then modified with different concentrations of $NaHSO_3$ (0g/L to 15 g/L) during the isolation process. As the $NaHSO_3$ concentration increased, the canola protein recovery rate

increased whereas canola protein purities decreased. Amino acid composition results showed that the hydrophobic amino acids in canola protein constituted only 27%, indicating that canola protein is mostly hydrophilic. The greatest wet shear strength of canola protein adhesive without modification was 3.97 MPa with 100% wood cohesive failure (WCF), observed at a relative high curing temperature. $NaHSO_3$ had slight weakening effects on the adhesion performance of canola protein. (KY) It has been experimentally demonstrated that during the conversion of cellobiose by *Clostridium thermocellum*, increased pressure and increased dissolved hydrogen gas concentrations shift the acetate/ethanol ratio in favor of ethanol production. However the mechanism underlying this shift has not been elucidated. MFA and FSA are useful tools for evaluating metabolic models and provide indicators of the confidence with which we can ascribe biological significance to model prediction. The catabolic pathway consisting of cellobiose conversion into acetate, biomass, ethanol, lactate, carbon dioxide and hydrogen formed the basis of the metabolic network. Product formation as a function of dissolved hydrogen gas concentration and the physical property of cell (geometry) was exploited by stoichiometric modeling based on a flux spectrum analysis (FSA). On average, ethanol to acetate ratios were predicted to increase from 0.21 (@ 0.1MPa) to 1.71 (@ 7MPa) and 8.83 (@ 17.3MPa) under conditions of increasing pressure and hydrogen fluxes across dilution rates. The model predicted the effect of even small amounts of dissolved hydrogen gas in the presence of pressure on *C. thermocellum* product selectivity. In the absence of pressure conditions across dilution rates, predicted average ethanol to acetate ratios increased from 0.20 (@ 0.1MPa) to 0.64 (@ 7MPa) and 1.84 (@ 17.3MPa). The spectrum of predicted ethanol and acetate yields under conditions of dissolved hydrogen gas concentration and hydrostatic pressures for the most part contained the corresponding experimental observations for ethanol and acetate yields.

Task 5: Develop and evaluate integrated process systems for commercial feasibility.
(WI) We use methods of techno-economic analysis to evaluate the feasibility of innovative biorenewable chemical production processes. We are evaluating systems based on polyketide synthesis combined with chemical catalysis to produce biorenewable chemicals in the pyrone and carboxylic acid families. We are also examining on-farm conversion systems utilizing sweet sorghum and sugar cane to produce a range fuels and chemicals. We use life cycle assessment techniques to assess the environmental impacts of processes to produce biorenewable chemicals and materials

Objective D. Identify and develop needed educational resources, develop distance based delivery methods, and develop a trained work force for the biobased economy.

Task 1: Serve as a knowledge resource base for biobased processing and products.
(IL) In January 2011, a short course on corn wet milling was held that focused on the fundamentals of the wet milling process. The course was taught by eight experts: four faculty, two USDA-ARS scientists and two speakers from industry. Nineteen attendees from wet milling and allied industries participated in the course. The Seventh International Starch Technology Conference was held June 5-8, 2011 which attracted approximately 60 participants from industry, federal research agencies and academia. Eighteen speakers from government research agencies and industry presented papers that were published in a printed proceedings. The conference agenda focused on technology related to various types of starch and biomass processes. In 2012, a short courses are planned that will focus on corn wet milling and on ethanol production technologies. These short courses will be taught by speakers from academia, industry and federal research agencies and be designed as an outreach activity to members of the starch and biofuels industries.

Task 2: Distribute new knowledge to train the work force and general public in biobased products and processing.
(IL) In January 2011, a short course on corn wet milling was held that focused on the fundamentals of the wet milling process. The course was taught by eight experts: four faculty, two USDA-ARS scientists and two speakers from industry. Nineteen attendees from wet milling and allied industries participated in the course. The Seventh International Starch Technology Conference was held June 5-8, 2011 which attracted approximately 60 participants from industry, federal research agencies and academia. Eighteen speakers from government research agencies and industry presented papers that were published in a printed proceedings. The conference agenda focused on technology related to various types of starch and biomass processes. In 2012, a short courses are planned that will focus on corn wet milling and on ethanol production technologies. These short courses will be taught by speakers from academia, industry and federal research agencies and be designed as an outreach activity to members of the starch and biofuels industries. (SD) A dry fractionation workshop for ~25 POET employees was held in June. The public workshop will be held in the fall of 2011.

Task 3: Develop and disseminate educational materials in high-priority topic areas.
(KY) Developed video lectures, slide sets, and comprehension check questions for lectures in Fundamentals of Biorenewable Resources and Biofuels Production and Properties courses. (AR) Application, # 2009-00926, ‘Biobased Products and Bioenergy Multi-University Graduate Program’ was funded by the USDA. The certificate will be offered fall 2011. Julie Carrier will deliver “Overview of biomass conversion” starting spring 2012. (OH) With the USDA Higher Education Challenge Program funded project “Biobased Energy Education Materials Exchange System (BEEMS)”, we have developed the following PowerPoint Presentation modules in the bioproducts and bioenergy area through the collaboration with peers in land grant universities: anaerobic digestion, biomass pretreatment, biodiesel, corn ethanol, enzymatic hydrolysis, butanol, gasification, pyrolysis, algae, microbial fuel cell, liquefaction, cellulosic ethanol, and feedstock logistics. The teaching materials are being reviewed and published by American Society of Agricultural, and Biological Engineering (ASABE). It is expected that more than 1000 students in the U.S. will be trained annually with the bioenergy education materials we developed. (HI) Khanal and his Graduate student Devin Takara have been developing a bioenergy laboratory manual for middle/high school teachers. The manual is expected to be completed and tested in October 2011. The manual includes some of basic concepts of physics, chemistry, Math and biology and their applications in bioenergy production. We tried to use as much as possible the locally available cost-cost materials in fabricating the set-up.

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Impacts

1. (TN) Results were shared with a renewable energy company (Genera Energy) to improve the feedstock supply to launch a new demonstration-scale cellulosic biofuels bio-refinery in Tennessee being funded by a $70M biofuels initiative by the state. Results apply to a DOE high-tonnage feedstock supply grant that involves numerous Original Equipment Manufacturers (OEM) that supply field equipment, and commercial and industrial storage, handling, and compaction systems.
2. (TN) Results were shared with a major renewable-energy company (DuPont-Danisco Cellulosic Ethanol) to address the impact of feedstock quality on enzymatic conversion of cellulosic biomass (switchgrass) to ethanol. Dupont-Danisco is a partner with Genera Energy on the Tennessee biofuel demonstration plant.
3. (TX) The invention disclosure filed with the Office of Technology and Commercialization of TAMU has resulted in the filing of a provisional patent for a fluidized bed gasification system for heat and power production. IP No. TAMUS 2814 and Provisional Patent with Serial No. 61/302,001.
4. (TX) The fluidized bed gasification technology developed at TAMU was licensed by SDL Citadel Global (Dallas, Texas) and is now working with TAMU to commercialize the technology for power generation using municipal solid wastes (MSW).
5. (TX) An invention disclosure was filed with the Office of technology and Commercialization of TAMU. IP No. TAMUS 3013.
6. (TX) AGIS model and a risk-based economic simulation model (Simetar) were developed to evaluate sustainability and economic indicators for use by potential industry collaborators or licensee.
7. (TX) The project has leveraged two other new projects funded by the State of Texas on similar topics.
8. (TX) New converting technologies were developed that can produce diverse cellulose materials, so that the economic viability of using cellulose feedstocks for bioenergy production would be significantly enhanced. Impact of this research was two-fold. First, it provided an eco-friendly method to produce renewable fiber and film products with benefits of increased carbon capture/sequestration, reduced energy consumption, and improved environmental protection. Second, it helped develop a balanced infrastructure of cellulose biomass production. With this establishment of infrastructure, on-farm manufacturing capacity for cellulose feedstocks would be enhanced.
9. (ND) Results on the physical, mechanical, and thermal properties of several species from the "NDSU Biomass Testing Laboratory at NGPRL" will help the farmers and ranchers of ND to assess the value of their biomass. A database of this nature benefits the producers, industry personnel, and researchers of the state and the nation as well.
10. (ND) The economical machine vision method of PSD determination of particulate biomass generated a lot of interest among personnel involved with biomass handing. A new ASABE standard creation (ASABE Committee FPE-709 and PM-23/7/2) on application of machine vision applied to forage and biomass is being lead by the NDSU.
11. (ND) The infield biomass bales transport study results serve as an excellent extension tool to inform producers/farmers of the state and the nation of the best method of colleting the bales and thus realizing time, energy, and cost saving.

12. (ND) The cold soak filtration, fatty acid composition, cloud point, and oil stability index test results help evaluate canola biodiesel quality traits of canola breeding program.
13. (ND) The application of bio-based epoxy resins in the production of composites materials helps decrease the dependence on petroleum-based resins, and may lead to a high added-value product from vegetable oils.
14. (KS) Development of biobased adhesives could significantly impact a >$100 billion industry sector that currently relies on petroleum-based feedstock with its attendant environmental problems. Large markets exist for plywood, particleboard, and coatings for construction and furniture, which represent huge demands for various adhesives. . The newly developed soy protein based latex adhesives can be cured at either room temperature or elevated temperature and showed high wet adhesion strength. Soy protein based latex adhesives have a great potential to replace or partially replace petroleum-based adhesives for wood veneer, labeling, and other applications.
15. (KS) Sorghum is a viable and renewable resource in Kansas, Oklahoma and Texas and other dry areas because of its high tolerance to heat and moisture stress. The utilization of sorghum biomass for biofuel production will lead to 1) capabilities to improve the utilization of sorghum biomass for biofuel production; 2) improvement in biomass conversion yields through optimization of pretreatment and enzymatic hydrolysis conditions; and 3) information to assist in the development of new and improved sorghum hybrids for biofuel production.
16. (MN) Our research outcome has contributed significantly to both the academic community and industry by generating breakthrough knowledge in *in situ* catalytic pyrolysis and hydrothermal liquefqaction of biomass, and catalytic reforming of biomass derived liquids and gases, and by developing innovative conversion systems. The research results obtained from this project had allowed us to seek and secure additional state and federal fundings to expand our research and development efforts. We established external partnerships with a number of technology focused companies including SarTec Inc, Luna Innovations, and New Generation Fuels, Minnesota Metropolitan Council Environment Services. The technologies developed through the project, if commercialized, have potential impacts on the US agriculture and energy sectors by promoting conversion of US grown biomass to liquid fuels, opening up more business opportunities, and bringing extra income to farmers. Many graduate students and junior researchers were trained through participation in the projects at UMN.
17. (IL) Addition of phytase resulted in better separations during enzymatic dry grind processing (E-Milling), resulting in coproducts with higher concentrations of protein and oil as well as reduced residual starch concentrations. This lead to higher ethanol concentrations during fermentation. Higher concentrations in coproducts and ethanol concentrations improves the overall economic robustness of corn ethanol production.
18. (IL) Found that protease can be used to generate free amino acids that supplement yeast growth during fermentation. This reduces the need for urea, which may lead to cost reductions. Processors using dry fractionation have difficulty with efficient fermentations, since endogenous nutrients from the kernel are separated prior to fermentation.
19. (IL) An optimized membrane filtration system was found to be less costly overall than a multieffect evaporator system. Membrane systems use less energy than evaporators and may prove attractive for future biofuel facilities.

20. (IL) Use of cooling tower blow down water (cooling tower water normally removed to waste treatment) in corn grain fermentation was found to be a feasible method to increase recycling in corn ethanol facilities. Fermentations using blow down water resulted in similar final ethanol concentrations and residual glucose levels observed with fermentations using deionized water.
21. (KY) Members of the committee collaborated to receive the following award: Nokes, S.E., M.D. Montross, C. Crofcheck, S. DeBolt, G. Halich, B. Knutson, C. Lee, B. Lynn, T. Mueller, S. Rankin, J. Seay, S. Shearer, S.R. Smith, Jr., T. Stombaugh, R. Anex (University of Wisconsin – Madison), M. Flythe (USDA-ARS), E. Webb (Oak Ridge National Laboratory), M. Chinn (NC State University), and M. Veal (NC State University). USDA-DOE Biomass Research Development Initiative. Project duration: 07/11 – 06/15. $6,932,786.
22. (MS) Breeding to reduce seed dormancy (to allow for rapid emergence) in lowland switchgrass was successful, resulting in a reduction in seed dormancy from 99.8% to 13% over 7 cycles of selection, and has resulted in licensing of 'Expresso' to Ernst Conservation Seed Company. Sweet sorghum and Energycane are being evaluated with USDA-ARS Houma LA, Sugarcane Research Unit.
23. (MS) A provisional patent (2nd generation catalyst) for syngas to gasoline was filed (61,189,084), a patent disclosure (3rd generation catalyst) for biomass derived syngas to liquid hydrocarbon was also prepared.
24. (CA) The results from acid pretreatment of sugar beet pulp for ethanol production have been disseminated to communities of interest including Novozymes (Davis, CA) and Chevron Technologies Ventures.
25. (CA) New process designs, approaches, and optimized conditions for achieving best management practices for storage, effective biomass pretreatment, hydrolysis and fermentation have been established. The new biomass pretreatment technologies can be applied to bioconversion systems, including anaerobic digestion and ethanol fermentation.
26. (CA) Research results from anaerobic digestion and the alternative two step method for conversion of cellulose biomass into biofuels have been presented to industry sponsor and collaborators, at scientific meetings, in research reports and articles.
27. (WI) The biomass characterization information was used to help guide the biomass supply chain development for several bioenergy projects including the UW Madison Charter Street Heating Plant upgrade project. The biomass data was supplied to the projects to enable planning for air emission control equipment as well as inform potential suppliers as to the suitability of their material.
28. (OH) We have developed a low-cost technology to transform crude glycerin into biopolyols and polyurethane foam. Poly Green Technologies LLC has licensed this technology from OSU and we are setting up the pilot scale system now. This technology is expected to generate 30-50 jobs in Poly Green in the next 3-5 years.
29. (OH) With the funding from USDA 1890 Capacity Building Program and US DOE through North Central Sun Grant, we have substantially increased the research capability of North Carolina A&T State University on biofuel research. This project has the potential to improve the economics of cellulosic ethanol process and POET has expressed interest in this technology, we will work together for the pilot scale testing.
30. (OH) With the BEEMS project, faculty from land grant universities have been worked together to share and develop bioenergy education materials, which will be reviewed by ASABE. This project has the potential to increase the quality of bioenergy education and reduce the faculty loading on preparation of course materials.
31. (HI) Results were shared with a Hawaii-based renewable energy company (Omni Green Renewables). The company received USDA SBIR Phase II grant in which our research team is lead University Partner.

32. (HI) Results were shared Hawaii’s middle school science teacher through presentation and Laboratory visit.