S-1041 Multistate Regional Project

The Science and Engineering for a Biobased Industry and Economy

2016 – 2017 Annual Report

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S1041 Vice Chair for 2016-2017

Executive summary

The annual report was compiled from individual station reports submitted by station representatives including outcomes and impacts against the S1041 objects, outputs, impacts, and target audiences. For a detailed description of each individual objective and task, see the project statement available on the NIMSS database website.

Stations reporting (Submitted by)
New York (Brian Richards, C. Lindsay Anderson)
Minnesota (Roger Ruan)
Nebraska (Deepak Keshwani)
Illinois (Kent Rausch)
Minnesota (Roger Ruan)
Mississippi (Fei Yu)
Tennessee (Alvin Womac)
Wisconsin (Troy Runge)

Project Objectives & Tasks

The objectives and tasks of the S1041 project are:

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

Task 1: Quantify and characterize biological feedstocks.

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

Task 3: Model and analyze integrated feedstock supply and process systems.

OBJECTIVE B. Improve biofuel production processes

B.1. Biochemical conversion processes

Task 1: Develop pretreatment methods for biological conversion processes

Task 2: Develop conversion processes

Task 3: Develop value-added products from hemicellulose and lignin

B.2. Thermochemical conversion processes

Task 1: Develop pretreatment methods

Task 2: Develop conversion processes

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

B.3. Biodiesel production processes

Task 1: Characterize new feedstocks

Task 2: Develop an understanding of fuel quality and performance issues

Task 3: Develop and characterize innovative processes for biodiesel production

Task 4: Utilize coproducts

OBJECTIVE C. Identify, develop and evaluate sustainable processes to convert biomass resources into biochemicals, biocatalysts and biomaterials (non-fuel uses)

Task 1: Discover and characterize biochemicals, biocatalysts, and biomaterials in biomass

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

Task 3: Develop applications for biochemicals and biocatalysts with biological activity

Task 4: Develop enabling technologies for biochemical production.

Task 5: Develop and evaluate integrated process systems for commercial feasibility

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

Task 2: Distribute new knowledge to train the work force and general public in biobased products and processing

Task 3: Develop and disseminate educational materials in high-priority topic areas.

Outcomes related to Objective A: Develop deployable biomass feedstock supply knowledge, processes and logistics systems that economically deliver timely and sufficient quantities of biomass with predictable specifications to meet conversion process-dictated feedstock tolerances.

NY:

Long-term study to determine if highest potential yields occur with binary mixtures of warm-season grasses vs. pure stands. Plots were sown in 2010 in Ithaca and Chazy, NY, and fertilized with 56 kg/ha of N fertilizer in the spring of each year. Averaging the past four years, the mixture of BoMaster switchgrass and Prairieview big bluestem ranked first in Ithaca (15.9 Mg/ha) and second in Chazy (12.7 Mg/ha). Big bluestem dominated (80-90%) mixtures with BoMaster switchgrass, but big bluestem was less than 5% of the mixtures with Cave-in-Rock switchgrass. Atlantic Coastal Panic grass stands deteriorated over the years at both sites, while other grasses persisted.

Two cultivars of switchgrass were grown on separate fields and harvested for seven years in the fall, and in the spring as either a standing crop or a fall-mowed crop, using conventional harvesting equipment. Recover of fall biomass yield the following spring ranged from 52 to 82%. Approximately 1% of dry matter yield is left in the field for each cm of stubble height following mowing. Bale moisture was very low in the spring, but was variable and high in the fall, averaging 22% for Cave-in-Rock switchgrass. Richards' first year participation included successful establishment of the new Liberty (a hybrid upland/lowland variety with increased yields) switchgrass on 4 acres of test strips. Due to severe drought, the summer 2016 seeding was not successful, and so was repeated in summer 2017 after persistent rains abated. We used no-till conservation planters to avoid plowing losses in soil organic matter. (The plowdown losses is soil carbon from the site's initial 2011 plowing are still being repaid). As is typical for switchgrass, N fertilization will not begin until 2018. Also supported in part has been continued analysis and publication of nitrous oxide emissions and soil carbon flux data from our marginal land site, which is being welcomed by collaborating modelers.

MN:

Producing and processing biomass feedstock locally is an alternative approach to centralized production and processing. One of our focuses is mass cultivation of microalgae on locally available wastewaters, be it municipal wastewater or animal wastewater or food processing wastewater. We developed and investigated strategies for water recycling and minimizing adverse effects of wastewater. The large water footprint and nutrients demand are two of the major bottlenecks for microalgae cultivation at industrial scale. In our study, a fed-batch cultivation system with post-harvest culture media recycling to reduce the usage of water and nutrients was studied. Pretreated anaerobic digestion swine manure was used to cultivate C. vulgaris for 7 days at different recycling ratios. The results showed that this alga grew well in this system with improved biomass productivity and nutrient removal efficiency. We also developed a new thermophilic AD process as pretreatment method to improve the nutrient profiles of animal wastewater for algae cultivation. In our study, a low vacuum was applied to the substrates before and during thermophilic AD for the purpose of removing ammonia and hydrogen sulfide from the AD system. We found that intermittent thermal vacuum stripping was very effective in stripping ammonia and hydrogen sulfide. The stripped ammonia and hydrogen sulfide were absorbed by a sulfuric acid solution and a sodium hydroxide solution to form ammonia sulfate and sodium sulfide. The significance of the vacuum assisted thermophilic AD lies in the ability of the novel AD process to effectively degrade organic matter in both municipal and agricultural wastewaters and generate high yield of methane while cost effectively stripping ammonia and hydrogen sulfide, resulting in a liquid having much lower nutrient loading and especially lower ammonia level, which is of importance and sometimes critical to the further use of the liquid for microalgae and aquaponic production.

TN:

Several years of field and commercial-scale experiments evaluated harvest and feedstock supply logistics with round bale and bulk-format created with a forage harvester; biomass size reduction pre-processes for energy crops and agricultural residues; harvest and transport vehicle logistics monitoring of up to 7 independently-operated vehicles along a biomass supply chain from field to local depot; storage, reclaim, and bulk flow handling behavior for various particle size distributions of switchgrass; storage losses for enzymatic conversions of lignocellulose materials stored either as low- or high-moisture (ensiled) feedstock; and feedstock quality along the complete supply chain for various handling scenarios as evaluated by liquid ammonia explosion pre-treatment and enzymatic hydrolysis. These technical findings were published in prior-listed refereed journal articles. An outcome of the specific technical research was the assembly of a technical basis along the feedstock logistics supply chain to conduct an accurate economic analysis. Realistic sizing of equipment parameters for documented flow throughput and energy use resulted in assemblies (and numbers) of equipment systems to achieve the technical supply of milled biomass into the throat of a biorefinery. Specifically, low-moisture switchgrass logistics systems based on either bales or bulk format field harvests were compared based on road-side storage of bales or depot-storage of bulk format. Preliminary results showed similar costs per dry ton across harvest/logistics, not including farmer payments, with final costs ranging from $51 to $66/metric ton (Mg) range – for a wide range of diesel fuel costs.

Outcomes related to Objective B: Investigate and develop sustainable technologies to convert biomass resources into chemicals, energy, materials and other value added products.

MN:

We continue to conduct research on microwave assisted pyrolysis (MAP) and gasification (MAG) processes. We investigated fast microwave assisted pyrolysis of lignin, corn stalk, low grade coal, plastic wastes, municipal wastewater sludge and scum, individually and in combination. We also studied catalytic microwave assisted pyrolysis and in-situ and ex-situ upgrading. In a study of co-pyrolysis of corn stover and scum with CaO and HZSM-5 as the catalyst, we found scum as the hydrogen donor, had a significant synergistic effect with corn stover to promote the production of bio-oil and aromatic hydrocarbons when the H/Ceff value exceeded 1. The maximum yield of aromatic hydrocarbons (29.3wt.%) were obtained when the optimal corn stover to scum ratio was 1:2. In a study involving in-situ and ex-situ catalytic upgrading with zeolite HZSM-5 catalyst of vapors from microwave-assisted pyrolysis of lignin, the in-situ process in which the catalyst was mixed with lignin feedstock produced higher bio-oil and less char than the ex-situ process. The gas yield was similar for both processes. The ex-situ process had higher selectivity to aromatics and produced more syngas and less CO2 than the in-situ process. Additional experiments on ex-situ process found that the bio-oil yield and coke deposition decreased while the gas yield increased at higher catalyst-to-reactant ratios and catalytic temperatures. Higher catalytic temperature favored greater conversion of methoxy phenols to alkyl phenols and aromatics. Appropriate catalyst-to-reactant ratio (0.3) together with higher catalytic temperatures were favorable to syngas formation. Our new biodiesel process is able to convert high free fatty acid (FFA) oily wastes to ASTM standard biodiesel. New improved pilot microwave assisted conversion system and scum to biodiesel system were constructed and demonstrated.

NE:

Long-term research in the area of reactive extrusion for the production of substituted polysaccharides culminated in the issuance of a patent for a novel production method.

IL:

One way to increase DDGS value is to use pigmented maize as a feedstock for ethanol production. Pigmented maize has high anthcyanin content, and the anthocycnin imparts red, blue and purple color to the grain. The effects of anthocyanin in conventional (conventional starch hydrolyzing enzymes) and modified (granular starch hydrolyzing enzymes, GSHE) dry grind processes were evaluated. The ethanol conversion efficiencies of pigmented maize were comparable to that of yellow dent corn in both conventional and modified dry grind processes using GSHE. Total anthcyanin contents in DDGS from the modified process were 1.4 to 2.4 times higher than those of DDGS from the conventional process. These results indicated that pigmented maize containing high levels of anthocyanin did not negatively affect the fermentation characteristics of the dry grind process and revealed potential to use pigmented maize in the dry grind process, especially when using GSHE.

Mutations known to increase lysine and tryptophan concentrations were combined by breeding into two maize hybrid backgrounds that differ for grain protein concentration. Mutant hybrids were compared to their nonmutant control isolines for field performance and ethanol and DDGS processing using laboratory scale procedures: a conventional dry grind process and a modified dry grind process using granular starch hydrolyzing enzyme (GSHE). Mutant hybrid grain contained higher concentrations of a number of amino acids, with notable increases to at least 0.55% w/w lysine and 0.18% w/w tryptophan. DDGS yields increased for both mutant hybrids compared to controls. DDGS from mutant hybrids contained higher concentrations of lysine and tryptophan compared to controls. Using these mutant corn hybrids at an ethanol plant resulted in lower ethanol yields; however, this loss can be recovered with the higher DDGS yield and increased nutritional value of the DDGS.

A study compared distribution of anthocyanins (ANCs) in purple and blue corn coproducts from three conventional corn fractionation processes and linking ANC partitioning in different coproducts to corn kernel phenotype. Total monomeric anthocyanin (TA) from purple corn extract was 10 times more than blue corn. In dry milled purple corn, maximum ANCs were present in the pericarp and in wet milling they were concentrated in steepwater. For blue corn, the highest TA was in small grits and gluten slurry in dry milling and wet milling coproducts, respectively. HPLC showed the highest concentration of each ANC in steepwater for purple corn coproducts. Micrographs of kernel showed pigments concentrated in pericarp layer of purple but only in aleurone of blue corn. ANCs can concentrate in certain coproducts depending upon physical distribution of pigments in kernel.

Recently, transgenic sugarcane has been developed to accumulate sugars and lipids in stems, making it a promising dual-purpose feedstock to produce both ethanol and biodiesel. Two lines of the transgenic lipid producing sugarcane (lipidcane) and the nontransformed sugarcane were characterized and processed. By processing sugarcane stems with cane juice, about 90% of sugars and 60% of lipids were extracted with juice. Extracted sugars in juice were fermented to ethanol and lipids were later recovered from fermented juice using organic solvents. This study proved the concept of lipid and sugar coproduction from novel lipidcane, which have a potential to make a large-scale replacement of fossil derived fuel without unrealistic demands on land area.

Fouling affects the efficiency and environmental footprint of more than 200 biorefineries in the US. This study investigated: 1) effects of bulk temperature and initial probe temperature of the test apparatus on thin stillage fouling characteristics, 2) effects of exposure to evaporator heat treatment and 3) effects of facility shut down and cleaning on fouling characteristics. Experiments were conducted using model thin stillage (1% starch solution) and commercial thin stillage with varied temperature conditions. Increased initial probe temperatures increased fouling rates and maximum fouling resistances for commercial thin stillage and model thin stillage. At an initial probe temperature of 120C, higher bulk temperature (80C) increased fouling rates and reduced induction periods. Effects of heat treatment were not detected. Fouling tendencies were reduced after facility cleaning.

MS:

Dr. Fei Yu’s Bioenergy Research Group at Mississippi had continue to investigate the real biogas purification process and catalytic conversion for liquid fuels production. We designed nickel based catalysts for methane dry reforming, natural gas reforming, and real biogas reforming with addition of carbon dioxide for syngas production. The biogas based syngas could be used for liquid biofuel production. We also continued to screen iron based catalysts for aromatic-rich gasoline range liquid hydrocarbon production during catalytic conversion of syngas. The syngas conversion to higher alcohols was also addressed for the integrated biomass to biofuel conversion process.

WI:

We had several projects looking at lignin valorization in a variety of bioprocessing operations. The research looked at both genetically modified plants to increase functional groups like ferulates, as well as use solvent separation (gamma valerolactone) to isolate unique lignin moieties. We also performed research on new catalytic methods of isomerization of glucose to fructose, which is a key intermediate step for the biochemical conversion of dairy manure to liquid fuels and chemicals through the sugar platform. Finally, studies were conducted to investigate a wide range of chemical pretreatments on dairy manures to improve methane production during anaerobic digestion.

Outcomes related to Objective C: Utilize system analysis to support development of economically, socially and environmentally sustainable solutions for a bio-based economy.

NY:

This goal of this project is the development of an optimization framework that enables financial sustainability of a bio-based production processes, taking into account uncertainties and variability in feedstock cost and final product value. The resulting stochastic optimization framework is capable of determining optimal production scheduling, and contractual strategies for financial risk management and is implemented on a test case of a biochemical conversion process for the production of ethanol.

MN:

We conducted life cycle assessment of several technology strategies including aquaponic systems, scum to biodiesel process.

NE:

A techno-economic modeling framework was developed to investigate the impact of fed-batch enzymatic hydrolysis. A comparison of perennial grasses and corn-based biomass materials for producing biohydrogen was completed. An evaluation of corn biomass residues for the production of xylitol was conducted.

WI:

We developed mathematical models around manure processing and digestion. These models were used as candidate technologies in the farm optimization model, ANOMMOD, which assists producers design manure processing and plan its utilization towards economic operation. These models are also useful for researchers conducting life cycle assessments on manure separation systems as lifecycle inventory data. We developed an optimization methodology used crop modeling outputs (EPIC model) to identify which fields should be harvested for two regions (around 4 counties each) in Wisconsin and Michigan to minimize environmental impacts while achieving desired biomass harvest quantities. This optimization algorithm is a multi-objective optimization where the minimized goal represents a combination of the investigated environmental impacts (global warming potential, eutrophication and soil loss).

Outcomes related to Objective D: Identify and develop needed educational, extension and outreach resources to promote the transition to a bio-based economy.

MN:

Biobased economy is a relatively new field, and therefore has high demand for human resources. Our project has trained many students and junior researchers who either took on industry or academic jobs that require knowledge of renewable energy technology. Many of our findings have found their way in classroom teaching. Our thermochemical conversion, scum biodiesel, and algae research activities have resulted in pilot scale facilities for demonstration to stakeholders.

NE:

A faculty development and educational research project related to Food, Energy, and Water Systems and systems thinking was initiated with funding from USDA Higher Education Challenge Grant. An Educational research project on the development of immersive simulation game on the Corn, Water, Ethanol, and Beef nexus was initiated with funding from National Science Foundation.

IL:

In January 2017, two short courses were taught: one on corn wet milling and one on fuel ethanol production technology. Each short course was taught by eight experts: four faculty, two USDA-ARS scientists and two speakers from industry. Sixty participants from wet milling, dry grind ethanol and allied industries participated in the courses. These workshops were designed as an outreach activity to members of the starch and biofuels industries. Graduate students presented their research posters to the participants during the workshops. In August 2017, as part of the

S-1041 annual meeting, a mini-symposium was held at the Western Regional Research Center (USDA-ARS) in Albany, CA. Papers and posters were presented and compiled into printed proceedings that were distributed at the symposium and posted on line. Proceedings will also be distributed to state and federal agencies.

Impacts related to station involvement with S1041 group

NY:

Over a seven-year period, spring switchgrass biomass was higher in feedstock quality compared to fall-harvested switchgrass, but recovery of overwintered switchgrass in the spring was strongly impacted by winter snowfall and rainfall patterns in the spring. Late fall harvest carries the risk of not being able to produce dry forage, while spring harvest carries the risk of losing up to half of the biomass. Binary combinations of warm-season grasses can have higher yields than pure switchgrass, but most species combinations are dominated by a single species.

MN:

Production of current major biofuels, i.e., biodiesel and ethanol, is competing with food and feed demands, prompting the need to use non-food biomass feedstock for biofuel production. Thermochemical conversion of lignocellulosic biomass feedstock is a platform which can provide short and mid-term solutions. The major challenges for thermochemical conversion are the poor quality and stability of the products, and costs associated with feedstock collection, handling, transportation and storage. In our project, we developed innovative microwave assisted pyrolysis and hydrothermal liquefaction processes, and designed systems suitable for distributed conversion of biomass. We also studied and developed technologies for mass cultivation and conversion of algae to biofuels and bioproducts.

NE:

A techno-economic analysis reveals the benefits of fed-batch enzymatic hydrolysis at a large-scale primarily being in the area of labor and energy savings.

IL:

1. Use of naturally occuring anthocyanins and pigments in specialty corn has great potential. Our work has identified advantages and barriers to adopting the using of this type of corn in commercial scale processes that can produce new biobased coproducts with high value along with biofuel. 2. Identifying corn genetics with enhanced amino acid profiles that also can be used to produce biofuel could expand or open new markets for distillers dried grains with solubles (DDGS) due to improved nutritional value. 3. Modified sugarcane that can produce significant amounts of lipids for biodiesel (lipidcane) could improve biofuel production on land areas not suited for annual row crops. 4. Temperature conditions were developed to allow more sensitive testing of fouling characteristics. This will allow us to conduct tests more quickly and repeatably, leading to more data that characterize fouling tendencies.

MS:

In collaboration with Ohio State University, University of Georgia, and Quasar Energy Group, we won a grant award from the USDA-BRDI program in 2012 to optimize biogas to liquid hydrocarbon production system, and established a continuous process to enhance the economic profitability of bioenergy system.

TN:

The complexities to supply a commercially-consistent feedstock of biomass at predictable specifications involves not only the target specifications for conversion, but also required specifications of biomass feedstock for efficient handling, conveyance, and reduced plugging, in addition to increased bulk density and reduced moisture retention for quality under aerobic conditions.

Peer-reviewed Publications

Anderson: Cheng, L., Martínez, M. G., & Anderson, C. L. (2016). Long term planning and hedging for a lignocellulosic biorefinery in a carbon constrained world. Energy Conversion and Management, 126, 463-472. http://dx.doi.org/10.1016/j.enconman.2016.08.017

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M. Srivastava, L.P. Walker, C. L. Anderson. Analysis of the Impact of Parametric Uncertainty on Lignocellulosic Ethanol Production Outcomes. In preparation for submission to Biomass and Bioenergy.

Cheng, L., & Anderson, C.L. Too Conservative to Hedge? How Much Does a Corn Biorefinery lose? International Journal of Production Economics (Accepted for publication)

Richards: Mason, C.W., C.R. Stoof, B.K. Richards*, S. Das, C.L. Goodale, T.S. Steenhuis. 2017. Hotspots of nitrous oxide emission in fertilized and unfertilized perennial grasses on wetness-prone marginal land in New York State. Soil Science Society Am. J. 81:450-458 DOI: 10.2136/sssaj2016.08.0249

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Irmak, S., H. Canisag, C. Vokoun, B. Meryemoglu. 2017. Xylitol production from lignocellulosics: Are corn biomass residues good candidates? Biocatalysis and Agricultural Biotechnology 11, 220-223.

Virtanen, S., Chowreddy, R.R., Irmak, S. et al. J Polym Environ. 2016. Food Industry Co-streams: Potential Raw Materials for Biodegradable Mulch Film Applications https://doi.org/10.1007/s10924-016-0888-y

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Huang, H., Moreau, R.A., Powell, M.J., Wang, Z., Kannan, B., Altpeter, F., Grennan, A.K., Long, S.P. and Singh, V. 2017. Biocatal. Ag. Biotechnol. 10:148-155.

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Ramchandran, D., Moose, S.P., Low, K., Arp, J., Parsons, C.M. and Singh, V. 2017. Ethanol yields and elevated amino acids in distillers dried grains with solubles from maize grain with higher concentrations of essential amino acids. Ind. Crops Prod. 103:244-250.

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Bao, Z., Y. Lu, and F. Yu*. 2017. Kinetic Study of Methane Reforming with Carbon Dioxide over NiCeMgAl Bimodal Pore Catalyst. AIChE Journal. DOI: 10.1002/aic.15579

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Womac, A.R., M.D. Groothuis, C. Dye, S. Jackson, and K. Tiller. 2017. Solid waste compactor and ejector transfer system performance with bulk switchgrass. Transactions of the ASABE 60(2): 263-274, (doi: 10.13031/trans.11966).

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Cronin, Keith R., Troy M. Runge, Xuesong Zhang, R. César Izaurralde, Douglas J. Reinemann, and Julie C. Sinistore. "Spatially Explicit Life Cycle Analysis of Cellulosic Ethanol Production Scenarios in Southwestern Michigan." BioEnergy Research 10 (2017):13-25.

Mahmoud Sharara, Apoorva Sampath, Laura W. Good, Amanda S. Smith, Pamela Porter, Victor M. Zavala, Rebecca Larson, Troy Runge. Spatially explicit methodology for coordinated manure management in shared watersheds. Journal of Environmental Management, 192 (2017): 48–56.

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Dissertations

Anderson: Lingfeng Cheng, Ph.D. Thesis: Optimal Production Planning and Hedging For Bio-Energy Industry. Accepted May 2017. Richards: Das, Srabani, 2017. Soil carbon dynamics in wetness-prone marginal soils under perennial grass bioenergy crops of northeastern United States. Ph.D. Dissertation, Cornell University.

Ramchandran, D. 2017. Effects of corn quality and storage on dry grind ethanol production. Ph.D. thesis. University of Illinois at Urbana-Champaign. Urbana, Illinois. Somavat, P. 2017. Evaluation and modification of processing techniques for recovery of anthocyanins from colored corn. Ph.D. thesis. University of Illinois at Urbana-Champaign. Urbana, Illinois. You, J. 2017. Effects of nitrogenous substances on heat transfer fouling using model thin stillage fluids. Masters thesis. University of Illinois at Urbana-Champaign. Urbana, Illinois.

Presentations

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Target audiences

NY:

The target audiences for this work are 1) academic researchers and regulatory/policy conducting sustainability assessments, but even more importantly 2) growers (and their advisors) who will be better able to site, plan and manage bioenergy crops, and will benefit from greater confidence in the yields and sustainability of a bioenergy cropping system that is compatible with current farming practices.

MN:

Our research findings were publicized to the academic community through peer-reviewed publications and conference presentations. On-site demonstrations were conducted to showcase our results to a broad range of audience including academic researchers, government officials, funding agencies, students, entrepreneurs, and the general public. Some research findings were brought to classroom teaching. Graduate and undergraduate students were involved in the research projects.

NE:

Researchers and industry professionals working in the biofuels and bioproducts area. Faculty and students who teach courses related to the bioeconomy

IL:

Our target audience covers a spectrum from crop producers to end users. On a regular basis, we meet with and disseminate information to crop producers, crop genetics industry, agricultural chemical companies, commodity production groups (e.g., Illinois Corn Marketing Board, National Corn Growers Association), grain industry groups (e.g., North American Millers Association, Corn Refiners Association), corn processor representatives, and government regulatory agencies.

MS:

Our target audience for this work includes commercial growers and manufacturers of biofuels and other scientists in the field of biomass or biogas conversion into liquid fuels.

TN:

Original Equipment Manufacturers (OEM) are targeted for the design, manufacture, and market equipment systems related to the harvest, handling, storage, transport, densification, pre-processing, and conversion of biomass to fuel and co-products. In other words, the target considers the potential new cellulosic biofuels industry for farm-to-biorefinery. Farm producers, biomass supply logistics firms, truckers, and biorefineries are targeted for the impact of supply logistics on conversion processes. Farmers are an important target for creating economically-viable biomass feedstock supplies since they make important decisions regarding the production and harvest of biomass crops to meet specifications acceptable to downstream conversion processes. Supply logistics firms can affect the quality of biomass since exposure to climatic elements affects biomass degradation and introduction of inhibitors. Truckers move biomass from farms to depots and/or biorefineries and possibly other points along the supply chain. Their understanding of moving biomass with seasonal harvest constraints and specification quality are paramount in the successful deployment of a supply chain. Biorefineries need of understand the importance of defining target biomass specifications that affect their processes, and the acceptable range of tolerances as it affects the cost of supply and conversion.

Synergistic activities

MS: We are continuing to participate in the USDA Biomass Research and Development Initiative (BRDI) project collaborating with Ohio State University, University of Georgia and industry collaborators such as quasar energy group (quasar), American Electric Power (AEP), Aloterra Energy, Marathon, and Case IH. Our semi-continuous process for biogas conversion into liquid hydrocarbon contains biogas purification, methane dry reforming, and catalytic conversion steps.