

Annual Review 2013

BAE BULLETIN

Department of Biosystems and Agricultural Engineering

Food Quality, Safety and Biosecurity

Renewable Bioenergy Systems

Sustainable Ecosystems



Integrating Engineering and Biology since 1906

BAE Bulletin

Since 1906, the Michigan State University (MSU) Department of Biosystems and Agricultural Engineering has responded to the changing needs of society by integrating and applying principles of engineering and biology in a systems context. Today, biosystems engineers at MSU solve complex, rapidly changing problems related to maximizing food quality and safety, preserving ecosystems, protecting health and homeland security, utilizing biomass and developing renewable energy.

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The Michigan State University (MSU) Department of Biosystems and Agricultural Engineering offers a Bachelor of Science degree in Biosystems Engineering (BE). A second undergraduate degree, Technology Systems Management (TSM), is currently under moratorium and being reviewed as a minor. A third undergraduate option is a two-year certificate program in Electrical Technology (ET) offered through the Institute of Agricultural Technology that leads to certification as a licensed journey electrician and master electrician. The department also offers an M.S. and Ph.D. program in Biosystems Engineering. With approximately 250 students enrolled in various programs, we take pride in knowing each student's name.

In addition to teaching, faculty members are actively involved in conducting leading-edge research and Extension activities.

Visit www.egr.msu.edu/bae to learn more about the degree programs offered by the MSU Department of Biosystems and Agricultural Engineering.

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COVER PHOTOS:

Top row pictured left to right: Dr. Bradley Marks and Michael James conduct Salmonella inactivation tests with almonds; department researchers have developed and evaluated x-ray computed tomography (CT) for the non-destructive detection of internal defects in edible chestnuts; and Dr. Gail Bornhorst conducts an in vitro gastric digestion study.

Middle row pictured left to right: SEM images of the cell walls of corn stover that has been subjected to an alkaline oxidative pretreatment to improve its conversion to biofuel potential; Dr. Chris Saffron uses pyrolysis to produce liquid fuels from biomass; and the MSU South Campus Anaerobic Digester is in production.

Bottom row pictured left to right: floating wetland mats designed by students from the MSU Biosystems Engineering program and the Universidad de Costa Rica; building a watershed model to assess the impacts of climate change on water resources; and poplar trees grown in large-scale, sensed columns are used to assess food processing wastewater treatment and prevention of metal contamination in Michigan groundwater.

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Greetings from the Chair

Dear alumni and friends:

On behalf of the Biosystems and Agricultural Engineering faculty and staff, I am pleased to present our 2013 annual newsletter, in which we share just a few examples of our activities and accomplishments.

The past year has been another exceptionally exciting and productive one for our department. By every measure, our department continues a long-term positive trajectory in productivity and impact, with **significant increases in enrollment, external funding, and peer-reviewed publications**. Specifically, our enrollments have more than doubled in the past six years, with the biosystems engineering undergraduate and graduate programs now enrolling over 200 and 45 students, respectively, and with our graduates finding excellent placement in the food, ecosystems, bioenergy, and health sectors.

Additionally, our faculty members continue to acquire and manage **significant external funding from diverse and highly competitive sources**, such as NSF, USDA, EPA, the U.S. Army, and various foundations, state agencies, industry associations, and private companies – the largest recent grant being the \$25 million USAID-funded Global Center for Food Systems Innovations (gcfsi.isp.msu.edu). Although we are proud of our strong growth trajectory, I am especially proud of the degree to which our faculty members are **directly engaged with our stakeholders** in developing real solutions to critical challenges in each of our three focus areas:

- Food quality, safety, and biosecurity
- Sustainable ecosystems
- Renewable bioenergy

In particular, the international engagement of our faculty is increasing at a rapid rate, in education, research, and outreach. We now offer study abroad courses in Australia, Costa Rica and Germany/Sweden. Additionally, our faculty is involved in numerous international projects, including work in Costa Rica, China, Egypt, Ghana, India, the Philippines, and Uganda. For example, we have signed an MOU with Ain Shams University in Egypt to establish a Nano-Biosensor Center for Food and Environmental Protection. As we face many global challenges, such as

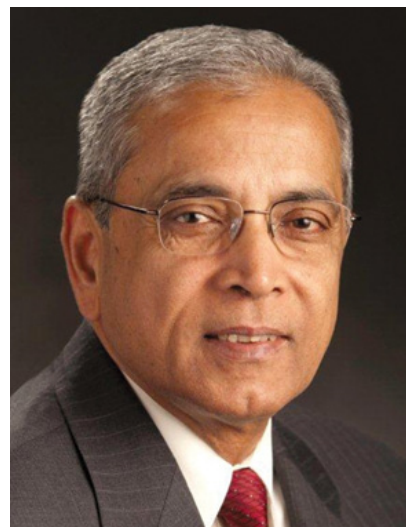
population growth, climate change, and pressure on natural resources, our department is well positioned to engage in these complex issues.

Within the department, a few personnel changes are highlighted later in this newsletter. Prof. Jim Steffe has retired. However, we are very excited that Dr. Jade Mitchell, a risk assessment expert, joined our department this past year as a tenure-stream assistant professor, and Dr. Gail Bornhorst recently joined the department as a visiting assistant professor with a focus on food digestion and health. Dr. Wei Liao was promoted to the rank of associate professor with tenure, and Dr. Bradley Marks has been appointed associate chair of the department.

I am extremely proud of all of our faculty members' dedication to our students and all of our stakeholders. Obviously, it is impossible for a single newsletter to capture their diverse contributions to our mission. Therefore, we have chosen to use this issue to highlight just a few current projects and programs in the area of renewable bioenergy, where our faculty and students are making important contributions to the discipline, to our state, and to the world, both in the laboratory and in full-scale implementations.

I hope you enjoy reading this newsletter. Please feel free to contact me if you are in this area and would like a tour. I think you will be impressed with how our team, department, and institution are making a difference in peoples' lives.

Sincerely, and with best wishes for the coming year,
Ajit Srivastava



Dr. Ajit Srivastava

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MSU positioned as a leader in repurposing waste as a resource

Converting biological waste products into energy isn't a new phenomenon for research institutions and programs to explore, but researchers in the Michigan State University (MSU) Department of Biosystems and Agricultural Engineering are taking the bold steps needed to position themselves as one of the country's leading academic and research institutions in this burgeoning field.

MSU biosystems and agricultural engineering researchers are seizing all available opportunities for converting wastes back into resources by cultivating relationships with and undertaking interdisciplinary research projects with university and industry colleagues in related fields. Their master plan for converting various types of biomass into affordable and environmentally sustainable commercial energy products encompasses several research layers: applied, basic, biological, chemical, supply chain and thermal. The process of systems modeling estimates feasibility and cost effectiveness from the bottom of the ladder – basic research – to the top of the ladder – commercialization – for each project.

Repurposing wastes is not a new concept – in fact, it's an old one – but it requires new technologies, practices and approaches in order to succeed at leaving a greener footprint here at home and around the world. MSU is prepared to advance that mission.

Examples of cutting-edge projects currently being conducted by researchers in the MSU Department of Biosystems and Agricultural Engineering to develop these new technologies, practices and approaches are featured on the following pages.

The fuel – Biomass

bio•mass\-, noun \ 'bī-ō-,mas\

1: the amount of living matter (as in a unit area or volume of habitat)

2: plant materials and animal waste used especially as a source of fuel

~a specific plant or substance used for bioenergy is called a feedstock, and it is generally converted into a more easily usable form

*Merriam-Webster

The product – Bioenergy

bio•en•er•gy\-, noun \ 'bī-ō-, 'e-nər-jē\

Renewable energy derived from energy (fuel) contained in living or recently living biological organisms, known as biomass

*Compiled from various sources

The process – Sustainable

sus•tain•able\-, adjective \ sə-'stā-nə-bəl\

sus•tain•abil•i•ty \-, stā-nə-'bi-lə-tē\ noun

sus•tain•ably \-'stā-nə-blē\ adverb

1: capable of being sustained

2 a: of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged <sustainable techniques> <sustainable agriculture>

b: of or relating to a lifestyle involving the use of sustainable methods <sustainable society>

*Merriam-Webster

Writing the genetic formula for the next generation of biofuels

Protein engineering lab strives to come up with game-changing answers to bioenergy equation

By Sara Long

Having access to novel new proteins may be just what engineers need to rectify some of the inefficiencies associated with using plant biomass to replace petroleum in the production of jet fuels and chemical-based products such as resins and plastics. Investigators based in a new protein engineering research program at Michigan State University (MSU) have been charged with figuring out how to design and engineer these new functional proteins. Leading the initiative is Dr. Timothy Whitehead, an MSU assistant professor with a joint appointment in chemical engineering and material sciences and biosystems and agricultural engineering, and the recipient of a prestigious National Science Foundation (NSF) Faculty Early Career Development (CAREER) Award.

“We engineer and design life,” Whitehead says. “DNA is essentially translated into proteins that do the functions in the cell. It’s possible to read and write the genetic code from organisms fairly inexpensively nowadays and we have been able to design computational ways to create proteins. We’re now able to try to engineer new biological processes, such as developing proteins to treat the flu. We imagine biological components and processes from the ground up.”

The two-year-old research lab is funded by multiple federal grants, including two NSF grants, a National Institutes of Health (NIH) grant, and a grant from the U.S. Department of Defense. In addition to Whitehead, three graduate students, one post-doctoral candidate and 10 undergraduate and high school students collaborate on research projects in the state-of-the-art lab.

To make it easier for engineers and scientists to produce the next generation of renewable energies and bio-based products more economically and sustainably, researchers in the Whitehead lab are attacking critical inefficiencies in converting bio-



Dr. Tim Whitehead, a recipient of the prestigious National Science Foundation (NSF) Faculty Early Career Development (CAREER) Award, is director of a new protein engineering research program at Michigan State University. Researchers in this novel new laboratory are designing functional proteins geared at making it easier to use plant biomass as a replacement for petroleum in the production of jet fuels and chemical-based products such as resins and plastics. *Photo provided courtesy of MSU Office of Communications and Brand Strategy.*

mass to biofuel. The most critical problems occur in producing feedstocks, deconstructing biomass into fermentable substrates, and converting these substrates into fuels and chemicals. The team has successfully identified several problems on the deconstruction and conversion side where protein engineering may play a key role.

Especially challenging is cellulose, the main component of many plants, because unlike starch it doesn’t break down easily into glucose. Costly enzymes, or protein catalysts, then are added to expedite the process. One graduate student is working on an NSF-funded research project to recover the enzymes and recycle them back into the process. By recycling these enzymes, not as many will need to be used or added and this will help make the process more cost-effective.

Another project is working alongside Dr. Chris Saffron (see related story on page 12), who is heating up biomass in the absence of oxygen to create a bio-oil, a water-soluble and insoluble component, that can be used as heating oil. *Continued on page 9.*

MSU researchers making strides in biofuel production

Answering fundamental biology questions is first step in quest to develop next-generation fuels

By Sara Long

Since joining the Michigan State University (MSU) community in 2010, assistant professor of biosystems and agricultural engineering Yan “Susie” Liu has applied her expertise in microbial processing towards advancing the field of biofuel production. Her efforts have focused on developing new strains of algae and fungi to accumulate starch and lipid compounds that can be used as ingredients in producing fuels and other high value bio-based products.

Liu’s microbiology research has escalated in importance because of the ever-growing concerns over rising global demand for energy, using food crops for fuel production, and identifying alternatives to fossil fuels. Non-edible sources, such as carbon

dioxide (CO₂) and lignocelluloses (plant dry matter, or plant biomass), are promising alternatives because of their abundance and the huge reduction in greenhouse gas emissions that results when they’re utilized to produce biofuel.

Randomly using any type of biomass to generate renewable energy, however, is not a cut-and-dried process. Liu and her colleagues are



Dr. Susie Liu



The signs for potentially commercializing next-generation biofuel technologies are encouraging. The National Science Foundation has expressed interest in pursuing non-food-starch-based and lipid-based biofuel production, and agricultural producers and biofuel company in both China and India want to collaborate on the concepts developed in Liu’s lab repurposing agricultural residues in their country. Pictured here is a transgenic algal culturing system, used to convert CO₂ into starch and enzymes to produce bio-alcohol. *Photo provided courtesy of Dr. Liu.*

attempting to solve this dilemma by applying right microbial processes on particular carbon sources to handle the biofuel conversion and maximize carbon utilization efficiency. Liu’s group has constructed a transgenic alga to convert CO₂ into starch and enzymes to produce bio-alcohol. In addition, they are working on a novel lignocellulosic jet fuel production system that integrates co-hydrolysis and fungal fermentation to convert the majority of carbon available in lignocelluloses into bio-jet fuel. Both algal and fungal systems are producing the mono-sugars (glucose and xylose) as the intermediates needed for final biofuels production.

“Our objective is to create effective, efficient and economical production processes,” Liu said. “We are not only working on developing the science, but we’re also always thinking about how the product or process can be commercialized in the future.”

Continued on page 9.

Turning energy consumers into energy producers

Converting wastewater facilities into power plants

By Sara Long

It's hard to imagine, but about 60 million tons of food waste and 45 billion tons of sewage are disposed of annually in the United States. Treating these wastes requires a lot of water and energy at a cost to the environment, the municipalities who manage these facilities, and the public who pays taxes and sewer bills. Researchers in the Michigan State University (MSU) Department of Biosystems and Agricultural Engineering are seeking ways to reduce or eliminate this negative cycle by designing smarter approaches to repurposing these types of waste.

According to Dr. Wei Liao, MSU associate professor of biosystems and agricultural engineering, the ultimate goal is to transform traditional wastewater facilities into waste utilization facilities, or power plants. Liao's research emphasizes

integrating solar, biological and nano technologies to convert the wastes that enter the facilities into useable energy and potable water.

"Wastewater treatment facilities are capable of using anaerobic digestion to create energy, but the energy generated by anaerobic digestion alone is only able to cover a small portion of the energy required to conduct the treatment. A lot of energy and capital costs still need to be invested to turn wastewater into potable water," he says. "Our



Dr. Wei Liao

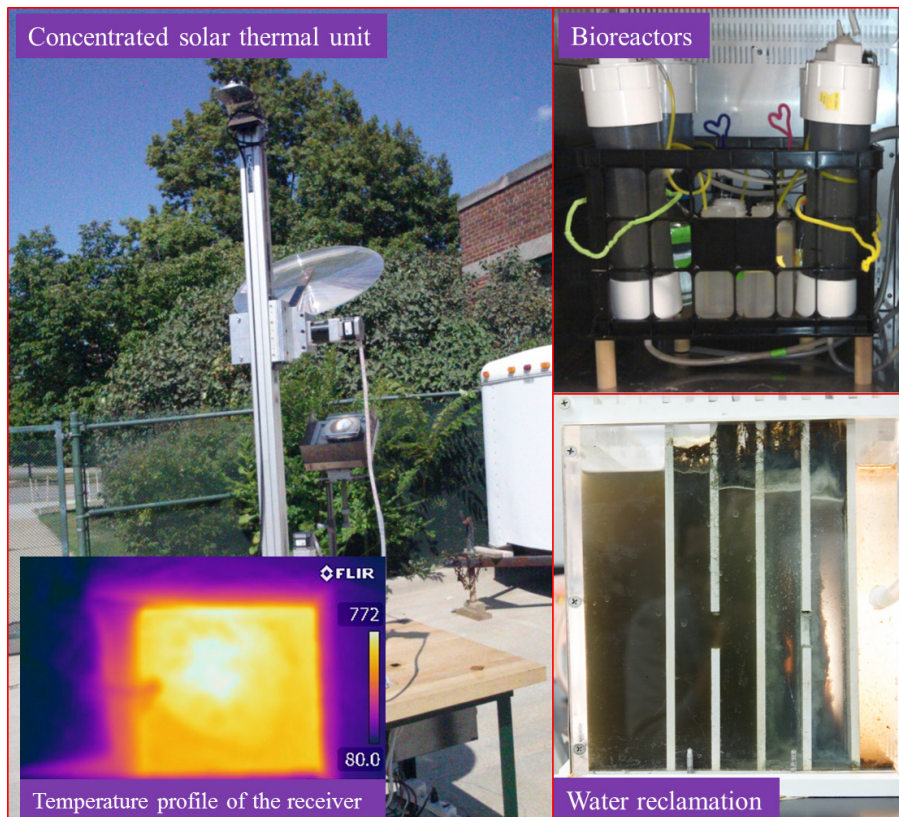
work is focused on applying a systems approach to develop the best treatment system, and make it feasible to produce potable water."

Using the technologies being developed at MSU, Liao and his colleagues are combining solar power and anaerobic digestion to produce energy and electricity in a related project in Costa Rica (see story on page 14) and electricity and potable water in a project funded by the U.S. Department of Defense.

"Water and energy are like twins – you can't separate them," Liao states.

"Energy is the profit piece, but clean water is good for everyone," he says. "Water is a huge issue. Some countries have little or no clean water or clean water utilities."

Continued on page 9.



This slide illustrates how a self-sustaining wastewater utilization system converts wastewater into bioenergy and clean water. The process uses heat generated by the sun to biologically convert methane into bioenergy and reclaimed water. *Photo provided courtesy of Dr. Liao.*

Writing the genetic formula for the next generation of biofuel-sat up biomass conversion options

Continued from page 6:

“Over time the water-soluble portion degrades and becomes pretty nasty,” Whitehead says. “We are trying to create an enzyme that can directly convert the main component of the water-soluble portion into value-added chemicals like succinic acid. This is an example of taking biomass, deconstructing it and creating enzymes to create bio-products.”

It’s always important to keep the economics of the overall biomass-to-fuel production process in mind.

“We have to consider the cost per ton of biomass and the per unit cost of having it delivered to your plant, the costs associated with breaking it down

into a fermentable substance, and then consider what value-added products can be made from that fermentable substance,” Whitehead explains.

Both of these projects have the potential to be game changers, but research is ongoing.

“We need to remain aware of the big picture, but also keep trying to identify the big game changers in different fields ranging from cancer biology to biofuels,” Whitehead says. “Our job is to focus our efforts on those things that can really be improved and try to develop proteins or biological components to fit those needs.”

MSU researchers making strides in biofuel production

Continued from page 7:

Liu is collaborating with an algal photo-bioreactor manufacturer in California to develop algal cultivation strategies that one day will be implemented in conventional power plants to uptake CO₂ and sequester carbon. Her group is also working with a biodiesel company in India to commercialize her fungal lignocellulosic bio-jet processes.

At MSU, besides being deeply committed to intensive research activities, Liu delivers Extension programs and outreach and teaches university classes.

“In my Extension role, I use my expertise to solve problems, such as developing value-added products from agricultural residues to help farmers increase their revenues. As a teacher, I develop new courses to teach students about fungal fermentation and that the process can result in lots of products,” she said. “It’s my job to solve problems and to contribute to the knowledge bank of tomorrow’s researchers, engineers and teachers.”

Turning energy consumers into energy producers

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“Even in Costa Rica, which is considered a developed country located between two oceans, 80 percent of its water is still untreated. The success of this project affects people’s daily lives.”

Another selling point is profitability: these solar bio-systems will not only clean and recycle water and produce energy simultaneously, but they will also generate profit on their own.

“Someday people will no longer need to pay for sewer systems or water treatment plants,” Liao says. “Instead, these facilities will be generating a profit. The technologies we’re developing link back to

achieving that goal.”

Liao emphasizes that systems integration is critical to the process’s success.

“I’m working on biological system approaches while my colleagues in the microbiology, chemical engineering, and mechanical engineering departments are working on microbiology, solar and nano technologies for waste-to-resource conversion.

“They are all connected,” he says. “People must work together to find solutions to emerging problems. It’s a systems approach.”

Got biomass? What happens next?

Recycling wastes into power is a win-win when using a systems approach

By Sara Long

The politics of environmentalism and people's independent views may swing back and forth, but at the end of the day everyone wins when wastes are transformed into useable resources. So says Dr. Steven Safferman, Michigan State University (MSU) associate professor of biosystems and agricultural engineering (BAE).

"The triple benefit of saving (financial) resources, preserving the environment and sustainability is a win-win," he says. "Everyone hears about environmental and greenhouse gas issues, but there are also sustainability issues as the global population nears nine billion people. We have to conserve the resources we have and find innovative ways to transform wastes into useful and profitable materials."

One tool BAE colleagues created to help advance the waste conversion process is the Michigan Waste Biomass Inventory to Support Renewable Energy Development (<http://mibiomass.rsgis.msu.edu/>). This tool identifies sites where waste biomass is produced across the state, focusing on prisons, wastewater treatment plants, farms, food processors, schools, universities, and land on which valuable high-energy biomass can be produced. The tool uses this data to estimate the net energy that may be available from the biomass and identifies constraints that could be limiting its conversion into energy.

"This tool estimates the locations and amount of waste within the selected radius at a target site and then figures out how much energy it theoretically can produce," Safferman says. "The tool serves two purposes. First, there is a fine line between earning and losing money. You can take cow manure and convert it into energy, but you may lose money doing that. Finding food waste and then mixing with the manure, however, can produce more energy potentially more economically and efficiently. Secondly, entrepreneurs and project developers can mine the database to determine the best locations to construct a

renewable waste to energy facility."

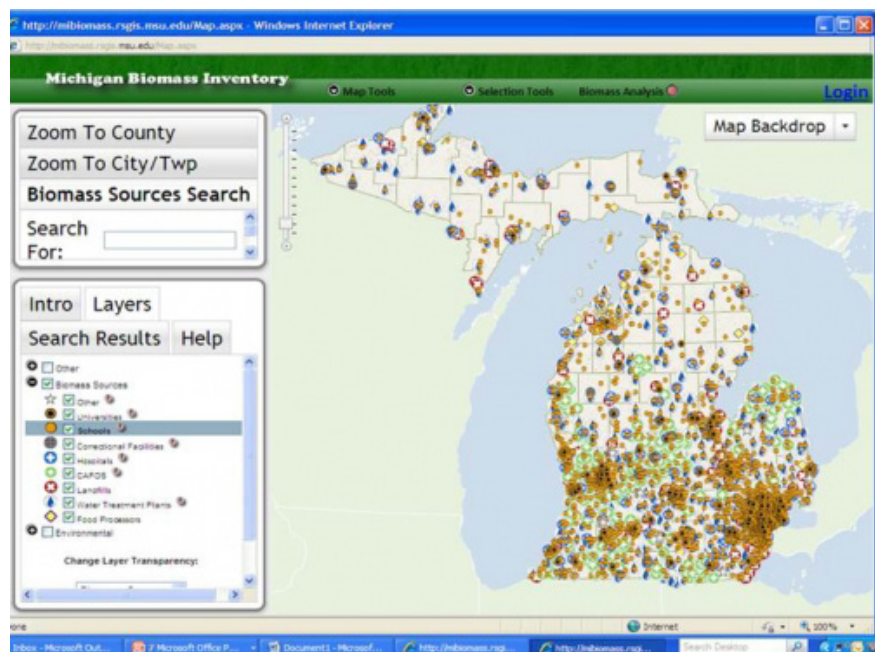
Before launching into a new renewable energy project, it's important to determine if the feedstock will work on paper. If it is theoretically feasible, laboratory investigations followed by pilot projects provide design data and enable the development of an engineering estimate of the project's costs and benefits. This systems approach maximizes the chances for success while minimizing development costs.

"It's not as simple as just producing energy," Safferman explains. "There are questions that have to be answered first. For example, is there a site available at which to produce the energy once you have the biomass, and then is there a way to transfer the energy to those who can use it once it's produced? Infrastructure, demand, and community acceptance has to exist."



Dr. Steven Safferman

Continued on page 16.



The Michigan Waste Biomass Inventory to Support Renewable Energy Development tool identifies sites where waste biomass is produced across the state.

Woody biomass holds promise as renewable energy source

Biomass supply chain logistics is emerging field in bioenergy

By Sara Long

Michigan may be a go-to source of woody biomass to fuel renewable energy projects now and into the future thanks to its plentiful forest acreage, available harvesting equipment, and supply of unworkable and marginally productive agricultural land that can be used to grow woody biomass. A promising source of renewable energy, woody biomass requires minimal time and capital investment, can keep pace with growing energy consumption needs, and continues growing even once it has been cut down.

Transitioning from natural forests to short-rotation plantations cultivated on land not used for other purposes comes with its own set of challenges, however. They range from having old equipment and outdated technologies to being able to break-even, identify best practices for converting and upgrading production, and protecting old growth. Since joining Michigan State University (MSU) in 2010 as an assistant professor of biosystems and

agricultural engineering, Dr. Fei Pan has been finding solutions to these questions and more.

Pan's initial work has focused on determining the profitability of harvesting and transporting woody biomass to processing facilities in Michigan. Even though the state has a long history of logging activities, no documentation existed that detailed harvesting productivity and costs. Similar cost analysis models exist for other parts of the country, but the Great Lakes region has different tree species and terrain conditions, each of which affects costs.



Dr. Fei Pan

Continued on page 16.



Woody biomass is a promising source of renewable energy because it can keep pace with growing energy consumption needs and requires minimal input compared to alternative biomass sources. Though Michigan has sufficient capacity to supply woody biomass to energy production plants year-round, more than 90 percent of the industry's harvesting equipment is over 10 years old. *Photo provided courtesy of Dr. Pan.*

Thermochemical processes heat up biomass conversion options

Bio-coal, bio-oil, bio-char are sustainable bioenergy and biofuel products

By Sara Long

Dr. Chris Saffron, Michigan State University (MSU) assistant professor of biosystems and agricultural engineering, compares his research to a stool having four legs: solid fuel, liquid fuel, renewable plastics, and systems analysis. The common denominator for each leg is to convert plant matter, a renewable carbon source, into higher-value fuels and products by applying heat in the absence of oxygen through processes known as torrefaction and pyrolysis.

To create solid biofuel, Saffron utilizes torrefaction, the thermochemical treatment of biomass at temperatures between 200 to 350°C in the absence of oxygen for several minutes, to convert biomass into a solid, dry, brittle and blackened material called torrefied biomass, or bio-coal. This process has generated interest because of the university's energy transition plan calling for 20 percent of campus energy to be produced from renewable sources by 2020.

One step toward achieving this goal was planting the first of six 10-acre plots of hybrid trees at MSU. The plot's trees will eventually be harvested, chipped and burned as a coal alternative at the T.B. Simon Power Plant, the single largest on-campus consumer of fossil fuels. Current estimates indicate that the Simon Power Plant produces 1.7 percent

of its energy needs by using untreated wood chips. Only one of the four boilers at the power plant is equipped to burn wood chips. The remaining three can burn only a fuel that handles exactly like coal.

By using a process called torrefaction, MSU scientists can create a material called torrefied biomass that is suitable for the boilers. Biomass plant material is roasted for a brief period of time to eliminate excess moisture and volatile chemicals. These chemicals can then be burned to power the process, and the result is a concentrated material that can be transported and burned exactly like coal. Working with the MSU T.B. Simon Power Plant, efforts are underway to test solid biofuel replacements for coal, monitor boiler efficiency, measure dust formation, and determine how much heat and power can be provided to campus facilities.

The second leg of the stool, liquid fuels, are much more challenging to produce, though they are up



Dr. Chris Saffron

to ten times more valuable than solid fuels. Using pyrolysis, biomass is heated in an oxygen-free environment to 400 to 600°C for several seconds, as opposed to minutes for torrefaction, to create a liquid known as bio-oil. Bio-oil is not oil, but a mixture of water and more than 100 organic compounds. Co-products include a non-condensable but flammable gas and solid biochar (one ton of biomass equals 0.7 tons of bio-oil, 0.15 tons of bio-char and 0.15 tons of combustible gas).



Torrefaction converts woody biomass (left) into a solid, dry, brittle and blackened material called torrefied biomass, or bio-coal (right). Photo provided courtesy of Dr. Saffron.

Continued on page 13.

Continued from page 12:

Bio-oil must be stabilized because it's reactive with itself, becoming more viscous as it ages. It is also corrosive to metal surfaces. Saffron's group, along with Professor James "Ned" Jackson in the MSU Department of Chemistry, is looking at the novel application of electrocatalysis to reduce this reactivity and produce a stable bio-oil that is compatible with metal infrastructure.

"Coupling electrocatalysis to pyrolysis is a unique contribution because it allows us to take electrons off the local power grid – preferably from wind or solar sources – to stabilize bio-oil, thus improving its properties. It's a different idea for making liquid fuels," Saffron says.

After stabilization, the bio-oil is transported to a refinery for hydroprocessing (using molecular hydrogen) to convert it to jet fuel, gasoline and diesel fuel. Saffron's research team has filed three patent applications on using electrocatalysis for treating bio-oil in this way.

Making the so-called "plant bottle" is the third area of Saffron's research. As with making liquid fuels, biomass is pyrolyzed to produce pyrolysis gas and char. The pyrolysis gas is then catalytically converted to aromatic chemicals such as benzene, toluene, ethylbenzene and xylenes. This mixture serves as the feedstock for making terephthalic acid, which is one of two monomers used to make plastic beverage containers. Such a process results in an entirely "green" bottle, as opposed to only 30 percent renewable, which is currently the case.

The final leg of Saffron's work is systems analysis. In addition to teaching a thermodynamics course, he teaches a course titled "Sustainable Bioenergy Systems" in which students apply the principles of economics and life cycle assessment to compare competing process concepts. This

course instructs students on assessing environmental benefits and burdens from cradle to grave, quantifying the costs and profits associated with the various engineering processes used to perform conversions, and determining the real cost to purchase biomassoline (green diesel or green gasoline) at the pump.

Saffron ties it together by saying that his research and teaching efforts contribute to preserving the three pillars of sustainability: environmental, social and economic. From an environmental perspective, climate change is real, and pyrolysis offers a chance to slow down and possibly stop global warming. Socially, it provides an impetus to wean ourselves off foreign oil to become energy independent and improve national security. Creating jobs in the biomass supply chain and developing profitable, value-added domestic markets will boost the country's economic health.

"Overall system sustainability results from the confluence of environmental, social and economic sustainability," Saffron says. "The tools available to the Biosystems Engineer are critical for assessing system sustainability."



Harvesting, chipping and burning woody biomass is one approach being utilized to help the MSU campus meet its mandate to convert to 100 percent renewable energy per the MSU Energy Transition Plan. *Photo provided courtesy of the MSU Department of Agriculture, Food, and Resource Economics.*

Lifelong Spartan leads two major waste-to-energy conversion projects

Projects demonstrate positive way to use biomass, reverses waste cycle

By Sara Long

Dana Kirk has been a Spartan his entire adult life, earning four degrees from Michigan State University (MSU) and now holding an assistant professor position in its Department of Biosystems and Agricultural Engineering. In 2011, he was selected to be the manager for a small scale solar thermal anaerobic digester project in partnership with the University of Costa Rica to convert food and animal waste into energy to power a village in the Central American country.

Kirk and fellow MSU Biosystems and Agricultural Engineering colleague Wei Liao worked closely with researchers at the University of Costa Rica to help improve life for the 19 million people (about half of the population) living below the poverty line in the Central American country. At the Fabio Baudrit Experimental Station just outside of San Jose, they constructed a small-scale, self-sustained renewable energy system that integrates solar and biological technologies to treat waste streams, generate power, produce fertilizers, and reclaim water.

Developing economical on-site renewable energy systems using agricultural and municipal waste streams will help rural communities in Central America increase access to affordable clean energy, advance development of low-emission and high-efficiency energy technologies, fight energy poverty,

alleviate environmental impacts of waste streams on air and water quality, and generate valuable by-products.

The project has a lot of benefits. It gets rid of waste, produces energy, and serves as a learning tool to see how well the system works and if it makes sense to use similar facilities in other places.

As the name implies, an anaerobic digester is an airtight tank with no oxygen. Organic waste (manure, food scraps, and other organic material) are put into the tank and heated to about 100°C for 20 to 30 days. Microorganisms in the manure break down the organic material, creating methane gas that can be burned for heat, as well as partially decomposed organic matter, water and nutrients



MSU assistant professor Dana Kirk is the manager of a small-scale solar thermal anaerobic digester project in Costa Rica and the newly launched South Campus Anaerobic Digester housed at the MSU Dairy Teaching and Research Center. *Photo provided courtesy of the MSU Office of Communications and Brand Strategy.*

that can be applied to crop fields as fertilizer. Working with colleagues in Costa Rica, Kirk and Liao are determining the effects of a tropical climate on the machine and testing a range of available organic waste materials.

The project was supposed to end in September, but Kirk and others are hoping to extend it.

“I want the end result to be that people in the industry in Costa Rica think about better ways to use waste,” he said. “I want this to drive policy change, challenge people to think creatively and put these systems into use.”

“We’ve had a tremendous amount of success,” he said. “We’re going to work with policy makers, educators,



This small-scale, self-sustained renewable energy system constructed in Costa Rica will help address future demands on energy and other resources in small- and medium-size rural communities.

Continued on page 15.

Continued from page 14:

and others to make sure we can continue. Something like this takes time and leaves us wanting to do more.”

Closer to home, Kirk is now heading a one-of-a-kind research initiative on campus that’s poised to have an industry-changing impact on small- and medium-sized dairy farms.

Kirk is the manager of the newly launched South Campus Anaerobic Digester (AD) housed at the MSU Dairy Teaching and Research Center. The digester will utilize about 17,000 tons of organic waste to generate 2.8 million kilowatt hours of electricity per year. The organic material the system will convert into energy includes cow manure from the farm’s 180 head of dairy cows, food waste from several campus dining halls, fruit and vegetable waste from the Meijer Distribution Center in Lansing, and fat, oils and grease from local restaurants into energy to power several buildings on campus. In addition, results from projects conducted at the South Campus AD may ultimately provide researchers with the knowledge that owners of small- and medium-sized dairies (farms with 200 head or fewer cows) need to successfully replicate the facility in their own operations to generate revenue and decrease carbon footprints.

The South Campus AD opened for business on August 13 and is the largest such system in volume and energy output on a college campus in the United States. The system will allow MSU to fulfill its teaching, research and outreach goals by providing a continuum from bench top to pilot scale to commercial scale digester systems on campus.

“This center will help us demonstrate how anaerobic digestion can be a stand-alone profit center for a small farm,” Kirk explained. “The digester built on the university’s 180-cow dairy operation has a proven technology with a business plan indicating a payback period of approximately 10 to 12 years. The unique thing about this project is that we’re generating about as much energy through this 180-cow system as we could on a 3,000-head dairy. This can be a big energy footprint from a small farm.”

In addition, the work with the South

Campus AD benefits partners such as Meijer who will now be able to tell quantifiable stories about sustainability to its clientele.

“Meijer can now tell its customers that this waste is no longer going to landfills and it’s going to be converted to energy and fertilizer. We’re demonstrating a financially sustainable way to generate energy, divert waste from landfills, reduce odor and help our industrial partners,” Kirk said.



The MSU South Campus Anaerobic Digester will utilize about 17,000 tons of organic waste to generate 2.8 million kilowatt hours of electricity per year. *Photo provided courtesy of the MSU Office of Communications and Brand Strategy.*



MSU dignitaries took part in a ribbon-cutting ceremony on Aug. 13 to officially open the MSU South Campus Anaerobic Digester. Pictured (L-R) are: Brian Breslin, MSU Board of Trustees; Gunnar VanDeberg, Wieland Davco; Bernie Sheff, Anaergia; Dr. Doug Buhler, director of the MSU AgBioResearch; Dr. Ajit Srivastava, chairperson of the MSU Department of Biosystems and Agricultural Engineering; and Chuck Reid, director of the MSU Land Management Office. *Photo provided courtesy of the MSU Office of Communications and Brand Strategy.*

Got biomass? What happens next?

Continued from page 10:

He adds that it's important to consider the big picture and think about multi-purposing.

"Can the energy produced from cow manure be used to power a nearby greenhouse?" Safferman asks. "Many municipal wastewater reclamation plants have anaerobic digesters. Can food processing wastes be blended with biosolids from these plants to produce larger amounts of energy?"

MSU researchers are exploring angles comprehensively and are attempting to identify potential unintended consequences and possible opportunities before they happen.

"We're assessing everything from value to environmental benefits in order to make the best decisions and help educate as to why some projects work and others don't," Safferman says. "There is no reason to create a silo when it comes to sharing

these mutually beneficial technologies. It's about conducting rigorous system level research and data analysis to help businesses make sound decisions based on the most complete information available."

One project demonstrating this approach involves helping a public utility select sites with the best potential for fulfilling their renewable energy portfolio so they don't invest in something that doesn't work. In the long-term, researchers hope to continue and expand these types of projects beyond public utilities. Another next generation project, for example, is geared at helping an alumnus figure out how to generate energy for his greenhouse using aquaculture.

"It's important that we look at bioenergy very broadly and seek ways to integrate biological systems to achieve greater efficiencies," Safferman says.

Woody biomass holds promise as renewable energy source

Continued from page 11:

"We are using machines designed for saw logs and not small-diameter biomass trees," Pan says. "Processing small-diameter trees would result in low productivity and bring up the cost, so our job is to figure out the break-even cost. Innovating harvesting and transportation equipment may be a possible solution, but it will be expensive."

Pan's second major research focus is characterizing the physical and chemical features of woody biomass material. Even though the material is delivered for upgrading, it still needs to be processed further before thermal treatment. Pan is developing a year-round Michigan-based performance model that compiles characteristics for field-stored biomass over a specific time frame and subject to humidity, weather and other variables. He conducted a biomass storage project in Escanaba to confirm whether or not it was possible to supply an upgrading facility with a year-round supply of biomass.

"In-woods storage of biomass is necessary because inclement weather restricts year-round harvesting, but we need to know if it would still be qualified for use after five or six months of storage," Pan says.

The best time to collect biomass turned out to be towards the end of August or early September because moisture was at its lowest levels. Towards the end of the year, moisture levels increase; too much moisture in the material adds to transportation costs because of the added weight. The ideal moisture content should be about 20 percent.

"The next question becomes how do you get the delivered biomass qualified to be upgraded? We need innovative engineering solutions to this problem," he says. "For me, it's going back to the big bioenergy picture. It's how to initiate and manage a forest stand, how to convert biomass into another form of energy, bridging those two parts with supply chain logistics."

"Biomass production is the upstream and converting or upgrading it is the downstream part. Harvesting, processing, and transporting the upstream-produced biomass for downstream upgrading in an economically feasible and environmentally friendly way is biomass supply chain logistics," Pan says.

Marks named associate chairperson of BAE

Professor receives Withrow Teaching Excellence Award and is a CIC-ALP Fellow for 2013-2014

Dr. Bradley Marks has been named the associate chairperson of the Michigan State University (MSU) Department of Biosystems and Agricultural Engineering. He currently leads an interdisciplinary research team that focuses on food safety engineering, particularly microbial inactivation modeling and improving methods for validating pasteurization processes for ready-to-eat foods. Marks' research program has been funded by competitive federal grants for more than 18 years. He also currently leads the MSU Food Safety Group, an interdisciplinary group of nearly 30 faculty members who focus on microbial food safety.

Marks earned his undergraduate and graduate degrees in agricultural/food engineering at MSU and Purdue University, respectively. He was an assistant and associate professor at the University of Arkansas prior to joining MSU in 1999. Marks has served as the MSU Biosystems Engineering Undergraduate Program Coordinator for more than 10 years and led the program through two successful ABET Accreditation review cycles.

Marks has received numerous teaching awards at the department, university and national levels. Most recently, he was awarded the 2013 Withrow Teaching Excellence Award from the MSU College of Engineering. This annual award recognizes outstanding performance by a faculty member in instructing, mentoring and supervising, and is selected primarily based on nominations submitted by students. Marks also received this award in 2002, 2007 and 2009.

Marks was also recently honored by the Committee on Institutional Cooperation (CIC) Academic Leadership Program (ALP). The group, composed of the Big Ten universities and the University of Chicago, selected Marks as one of its Leadership Fellows for 2013-2014.



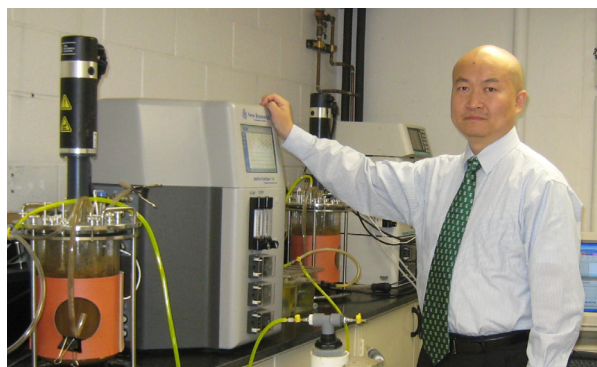
Dr. Bradley Marks

Liao promoted and granted tenure

Dr. Wei Liao with the Michigan State University (MSU) Department of Biosystems and Agricultural Engineering has been awarded tenure and promoted from assistant professor to associate professor. He also serves as the director of the MSU Anaerobic Digestion Research and Education Center (AD-REC).

Liao's research focuses on developing a novel concept to systematically integrate solar, biological and nano technologies to convert organic wastes into value-added fuels and chemicals. His research program is also working on creating a new application for using solid digestate as a biorefining feedstock. Liao manages a research partnership with the University of Costa Rica and oversees \$4.5 million worth of externally funded research and educational projects.

A member of the working group to develop "Science-based methods and technical guidelines for quantifying greenhouse gas sources and sinks in the forest and agricultural sectors" for the U.S. Department of Agriculture Climate Change Program Office, Liao is



Dr. Wei Liao

also a member of the editorial board for the Journal of Industrial Biotechnology.

Liao received his bachelors of science and master's degrees from the Wuxi University of Light Industry, China (B.S. '94, Fermentation Engineering and Technology; M.S. '96, Biotechnology) and earned his Ph.D. in Biological Systems Engineering from Washington State University in 2005. He joined MSU in 2007.

Lu awarded 2013 ASABE Fellow honor

Award is highest honor bestowed by society

By Sara Long

Dr. Renfu Lu, Michigan State University (MSU) adjunct professor of biosystems and agricultural engineering and supervisory research agricultural engineer and research leader with the USDA Agricultural Research Service (ARS), has been honored as a 2013 Fellow by the American Society of Agricultural and Biological Engineers (ASABE) for his outstanding contributions in the development and application of sensing technologies for property characterization and quality assessment of horticultural and food products.

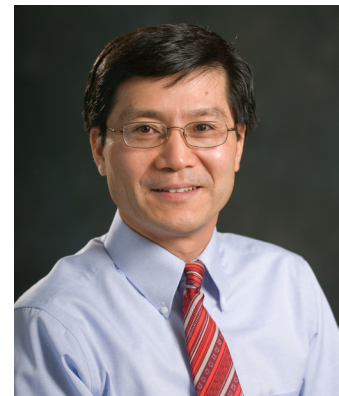
In his current role for the USDA ARS Sugarbeet and Bean Research Unit in East Lansing, Lu directs and supervises three U.S. federal government-appropriated research programs. His personal research is focused on the development and application of sensing technologies for nondestructive quality evaluation of horticultural and food products.

ASABE defines a Fellow as “a member of unusual professional distinction, with outstanding and extraordinary qualifications and experience in, or related to, the field of agricultural, food, or biological systems engineering. Recipients possess a minimum of 20 years of active practice in, or related to, the profession of engineering; the teaching of engineering; or the teaching of an engineering-related curriculum, and have been an active Member-Engineer or Member in ASABE for a minimum of 20 years.” Fellow is the highest honor awarded by ASABE to one of its members.

A few of Lu’s original developments include: new methods of determining and modeling rice milling

quality during and after the harvest season that have greatly expanded the knowledge and helped growers and processors better manage harvest and postharvest operations; the first three-dimensional computer simulation models for acoustic sensing of fruit firmness, which filled knowledge gaps in designing acoustic sensing systems and contributed to commercialization of the technology; and research in near-infrared technology that provided critical information and guidance on quality assessment, sorting and grading of horticultural products.

Lu has performed pioneering research in the development and application of hyperspectral imaging technology for food quality and safety inspection. Many of his innovations have been adopted by other researchers worldwide and have been featured or reported by national and international news media and industry magazines. Lu has authored or coauthored more than 200 research publications, including peer-reviewed journal articles, conference papers and book chapters, and given 174 technical presentations at scientific conferences, industry meetings, and research institutes and universities worldwide.



Dr. Renfu Lu



This in-orchard apple harvesting and sorting system (the first photo) can accommodate six to eight workers and automatically sorts apples into three quality grades (i.e., fresh market, processing and juice or cull) for color, size and/or surface defect, using optical imaging technology. Grading apples in the orchard would help growers achieve cost savings in postharvest storage and packing, reduce postharvest disease and pest problems, and enhance the inventory management. The second photo illustrates a scene in a commercial orchard in September of 2013, where people were examining the graded fruit in each fruit bin by the apple harvesting and sorting system.

BAE welcomes new visiting assistant professor Gail Bornhorst

Houghton, Mich., native Dr. Gail Bornhorst has joined the Michigan State University (MSU) Department of Biosystems and Agricultural Engineering as a visiting assistant professor. Bornhorst earned her bachelor's degree in biosystems engineering from MSU in 2007 and her master and doctorate degrees in biological systems engineering from the University of California, Davis (UC Davis).

Bornhorst's research interests are: designing innovative foods for health to optimize nutrient release in the gastrointestinal tract; developing functional foods by modifying the physical properties of food and the microstructure of food processing; determining the relationship between food rheological properties with the mass transport and absorption of food and pharmaceutical products; evaluating the experimental and computational analyses of mixing in food, biological and industrial settings; and accurately simulating physical and chemical aspects of digestion by developing dynamic in vitro gastric models.

A four-year recipient of the National Science Foundation Graduate Research Fellowship (2008-12), Bornhorst received the UC Davis Graduate School Fellowship (2008-09); the Henry A. Jastro Graduate Research Scholarship Award at UC Davis (2008-11); the Kellogg Company Outstanding Intern Scholarship (2008); and the MSU Senior Class

Council Outstanding Senior Award (Dec. 2007).

While at MSU as an undergraduate, Bornhorst completed a semester study abroad program at the University of Leon in Spain and internships at Nestle USA and the Kellogg Company. She was a visiting scholar at the Riddet Institute at Massey University in Palmerston North, New Zealand, while she completed her Ph.D. After finishing her Ph.D. and prior to returning to MSU, Bornhorst was a postdoctoral scholar at UC Davis for one year where she worked on the digestibility and breakdown of almond proteins in vivo and the mechanisms of food breakdown in vitro. She is also the author of seven peer-reviewed professional journal papers.

Bornhorst is an instructor for BE 478 (Food Engineering: Solids) and designing curriculum for a new course about engineering principles applied to food digestion and health systems.



Dr. Gail Bornhorst
Photo provided by the University of California, Davis.

Eisele receives 2013 BAE Outstanding Alumnus Award

Adam Eisele (B.S. '03, Biosystems Engineering), an environmental engineer with the U.S. Environmental Protection Agency (EPA), Region 8, in Denver, Colo., was the 2013 recipient of the Michigan State University (MSU) Department of Biosystems and Agricultural Engineering Outstanding Alumnus Award.

Eisele has been employed with the EPA, Region 8 since 2008 where he specializes in developing and applying advanced air quality monitoring tools. Prior to working with the EPA, he received his master's degree from the University of Colorado where he majored in both mechanical and environmental engineering. Eisele's thesis work focused on measuring air toxins at the urban/mountain interface along Colorado's Front Range. He was recently awarded a PECASE (Presidential Early Career Award for Scientists and Engineers) by President Obama for his pioneering research in air quality surveillance and method development.

Eisele and his wife Sara live in Boulder, Co. He enjoys mountaineering and skiing, Colorado microbrews and repeatedly selects the MSU Spartans to win the NCAA basketball tournament.



Adam Eisele

Evans receives 2013 MSU College of Engineering Distinguished Alumni Award

Kevin Evans (B.S. '87, Biosystems and Agricultural Engineering) was awarded the 2013 Michigan State University (MSU) College of Engineering Biosystems and Agricultural Engineering (BAE) Distinguished Alumni Award.

Evans is senior technical manager for Beam Global R&D. Since joining the company in fall 2012, he has played a key role in designing and building the new Beam Global Innovation Center in Clermont, Ky. Evans grew up on a dairy farm in south central Michigan with green and white running through his veins from the beginning: his dad, sister and brother all attended MSU before him. He worked his way through school in the agricultural engineering department, earning his bachelor of science in biosystems and agricultural engineering in 1987. Evans obtained his master's degree in biosystems and agricultural engineering from the University of California, Davis, in 1989.

Evans began his career at Frito-Lay, Inc., in Dallas as an R&D process engineer and acquired exposure across the portfolio of potato chips, extruded and salty snacks, and sweets. While at Frito-Lay,

he started to hone his skills and passion for process design and project management. In 1994, Evans migrated to Sara Lee Bakery in Chicago, where he continued to expand his consumer goods exposure in the bakery industry before moving to Florida to join Tropicana Products in 1997. There he developed strategic plans and business models for new technologies to drive productivity, quality and cost. In 2006, Evans transferred back north to Barrington, Ill., as the PepsiCo-Quaker-Tropicana-Gatorade R&D operations manager for the cross-functional operations teams that included pilot plant, health, safety and environmental, quality, project management and purchasing sub-teams. In 2008, Kevin moved into the role of director of commercialization and engineering for PepsiCo Beverage, taking responsibility for research and commercialization of new products and processes across the PepsiCo Beverage portfolio, including Tropicana, Naked Juice, Gatorade and Lipton Tea.

Evans has engaged in a variety of leadership and mentoring opportunities. He has chaired local blood drives, United Way campaigns and volunteered for



Kevin Evans (left) receives the 2013 MSU College of Engineering BAE Distinguished Alumni Award from Dr. Ajit Srivastava (right), chairperson of the MSU Department of BAE.

Junior Achievement; was an original PepsiCo trainer for diversity and inclusion initiatives; and was the founding member of the Quaker-Tropicana-Gatorade Toastmasters Club, twice achieving Gold Level Toastmaster status. Evans also served on the MSU Department of Biosystems and Agricultural Engineering industry advisory board for several years (chairperson 2007-2008) and mentored several MSU senior design project teams.

Kevin and his wife, Shay, reside in Louisville, Ky., with their two boys, Avery, 14, and Harrison, II. He enjoys traveling and also continues to spend many hours coaching and supporting his boys in their many endeavors ranging from sports to music to academic teams.

Piggott receives 2013 BAE Distinguished Alumnus Award

Scott Piggott (B.S. '98, M.S. 2010, Biosystems Engineering) was awarded the 2013 Michigan State University (MSU) Biosystems and Agricultural Engineering Distinguished Alumnus Award. Piggott, who was named the chief operating officer of the Michigan Farm Bureau in April 2012, is responsible for planning, managing and supervising all of Farm Bureau's ongoing programs and services.

Piggott started his career with the Michigan Farm Bureau in 2000 as its Natural Resources and Right to Farm Specialist. He was promoted to manager of the Agriculture Ecology Department in 2002 where his responsibilities covered environmental issues such as air quality and water quality and quantity. Piggott has served on more than 20 committees and boards and assumed numerous leadership roles, including co-chairmanship of the Michigan Agriculture Environmental Assurance Program and the Michigan Groundwater Conservation Advisory Council. He has been an invited fellow for environmental concerns at MSU, the University of Michigan and the University of Toronto.



Scott Piggott (left) is congratulated by Dr. Ajit Srivastava, chairperson of the MSU Department of Biosystems and Agricultural Engineering, for receiving the 2013 MSU Biosystems and Agricultural Engineering Distinguished Alumnus Award.

Piggott earned his undergraduate and graduate degrees in biosystems engineering from MSU, worked for the State of Michigan and designed air pollution control devices in public industry. He lives and works on his family's farm near Fowler, Mich., with his wife Donna and their four children.

Packard honored with posthumous degree

The late Michelle Packard, a Ph.D. candidate in the Michigan State University (MSU) Department of Biosystems and Agricultural Engineering, has been awarded a posthumous degree from the MSU Graduate School. Packard passed away July 4, 2012, after being struck by a stray bullet in a Lansing park prior to the holiday fireworks presentation.

Prior to her death, Packard's graduate research project had undergone a thorough peer review process and been validated as having significant scientific value and importance. She had also completed and/or submitted several professional papers to peer-reviewed professional journals, and was selected as a winner in the 2010 MSU College of Engineering Graduate School Awards.

"Michelle clearly earned this degree. Her work has been validated by professional peers and is now archived in journals, and for this you should be very proud," remarked Dr. Dan Guyer, MSU professor of biosystems and agricultural engineering, to Packard's family during the presentation. "We are not here today to shed tears, but rather to celebrate Michelle's hard work and accomplishments."

Packard's mother and sister were present to accept the award.



Michelle Packard was awarded a posthumous degree honoring the significant work completed during her graduate studies. Pictured left to right are: Elyse Packard, Michelle Packard's sister; MSU Graduate School Dean Karen Klomparens; Pamela Leidlein, Michelle Packard's mother; and MSU College of Agriculture and Natural Resources Dean Fred Poston.

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Department of Biosystems and Agricultural
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Xiaoqing Wang

Graduate Student Representative
Department of Biosystems and Agricultural
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Congratulations to the 2013-14 scholarship recipients!

Undergraduate Scholarships

Galen and Ann Brown Scholarship
James Burns

DeBoer Family Scholarship/Fellowship Fund
Jena Laur - Kristin Sanburn

A.W. Farrall Scholarship
Alexa Jones - Rachel Kurzeja

Clarence and Thelma Hansen Scholarship
James Burns - Matthew Gammans - Nathan
Jandernoa - Julia Otwell

Howard and Esther McColly Scholarship
Keely Chandler - Paige Crosset

George and Betty Merva Scholarship
Anh Bui - Stacey Stark

Graduate Scholarships

College of Engineering Outstanding Biosystems
Engineering (BE) Graduate Student Fellowship
Irwin Donis-Gonzalez

Graduate Scholarships (continued)

Galen and Ann Brown Scholarship
Niroj Aryal

Engineering Graduate Research Symposium
Awardees
(These students received travel grants in recognition of their
presentations.)

Shannon McGraw - Irwin Donis-Gonzalez -
Pichamon Limcharoenchat

Merle and Catherine Esmay Scholarship
Melissa Rojas-Downing - Subhasis Giri - Georgina
Sanchez

Bill and Rita Stout Scholarship
Rui Chen

Outstanding BE Graduate Student Fellowship
Zhenhua Ruan - Sean Woznicki

Outstanding BE Research Fellowship and Fitch
H. Beach Award
Dharmendra Mishra

Senior Design Showcase

About the Program

The Biosystems Engineering (BE) undergraduate program prepares graduates who will integrate and apply principles of engineering and biology to a wide variety of globally important problems. To achieve that purpose, the primary objectives of the BE program are to prepare graduates to:

- Identify and solve problems at the interface of biology and engineering, using modern engineering techniques and the systems approach, and
- Analyze, design, and control components, systems, and processes that involve critical biological components.

Additionally, the Biosystems Engineering Program is designed to help graduates succeed in diverse careers by developing a professional foundation that includes vision, adaptability, creativity, a practical mindset, effective communication skills for technical and non-technical audiences, the ability to work in diverse, cross-disciplinary teams, and a commitment to sustainability, continuing professional growth, and ethical conduct.

BE 485 / BE 487 Program

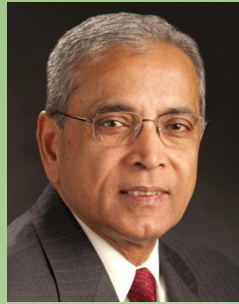
Every year, teams of Biosystems Engineering students, enrolled in the two-semester biosystems design capstone experience, BE 485/487, develop, evaluate, and select design alternatives in order to solve real-world problems. The projects are diverse, but each reflects systems thinking by integrating interconnected issues impacting the problem, including critical biological constraints. The engineering design process is documented in a detailed technical report. The project designs are then presented to engineering faculty and a review panel of licensed professional engineers for evaluation. A BE 485/487 capstone design team prepares and presents a design solution to industry, faculty, general community and peers that:

- Requires engineering design
- Combines biology and engineering
- Solves a real problem
- Uses a holistic approach
- Interprets data
- Evaluates economic feasibility
- Delivers a comprehensive, professional design report

Project Sponsors/Faculty Advisors

Aquaculture Research Corporation - Mr. Steven Srivastava
Biomedical Laboratory Diagnostics - Dr. John A. Gerlach
MSU Extension - Dr. Wendy Powers
JBT FoodTech - Mr. Scott Millsap & Mr. Bob Stacy
Ocean Spray® - Dr. Ferhan Ozadali
Tetra Tech - Ms. Valerie Novaes
DQY Agriculture Co. Ltd., China
Chestnut Growers, Inc.
Heat Transfer International - Mr. Dave Prouty
ConAgra Foods - Ms. Cassandra Edwards

Dr. Dana Kirk
Dr. Vangie Alocilja
Dr. Yan Liu & Dr. Jeff Li
Dr. Brad Marks
Dr. Kirk Dolan
Dr. Pouyan Nejadhashemi
Dr. Wei Liao
Dr. Dan Guyer
Dr. Chris Saffron
Dr. Shiny Matthews & Dr. Ajit Srivastava



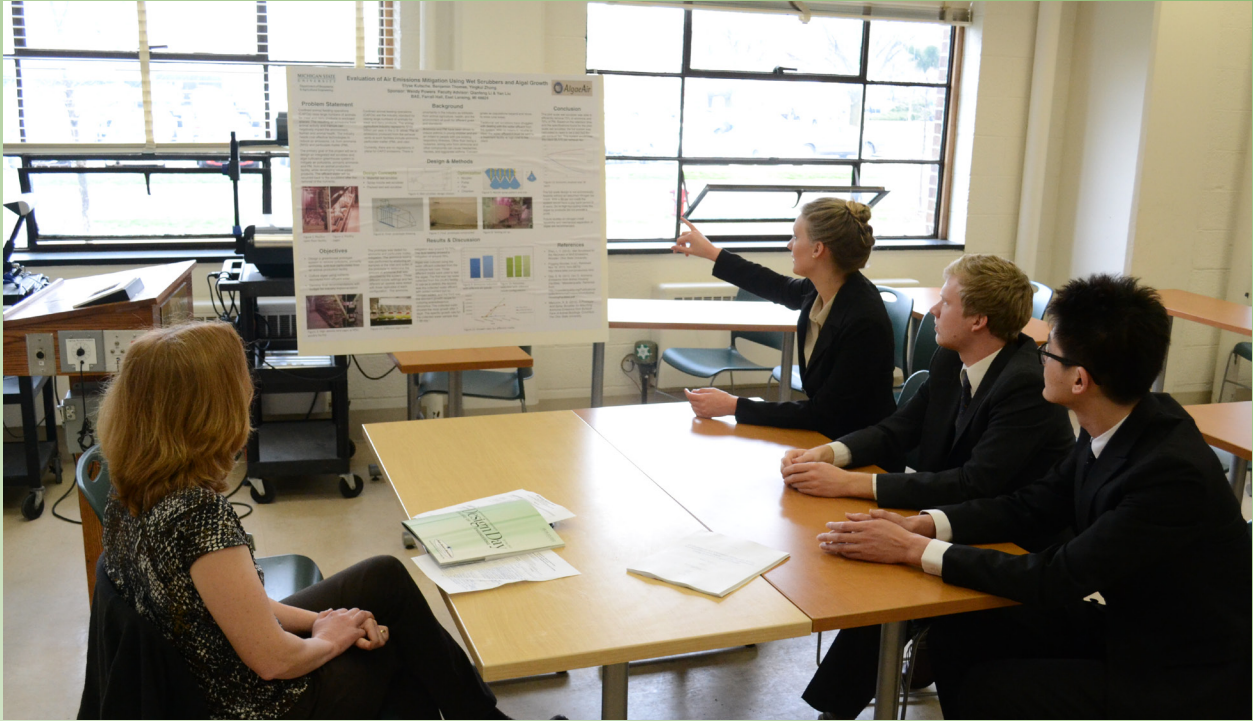
Dr. Ajit Srivastava, PE
Professor / Chair



Dr. Dana Kirk, PE
Assistant Professor



Dr. Luke Reese
Associate Professor



Practicing engineers serving as industry evaluators rigorously review each team's report for a number of criteria, including creativity, accuracy, proper design, following standards and correct technical format. Team members then receive feedback from the evaluators. Here, team members respond to the evaluator's questions by referring to their project poster, also utilized for Engineering Design Day.

Redesign of ProMix Batter Mixer Cooling Mechanisms

Regulations from the FDA require a batter mix added to food to be at 50°F or below in order to comply with food safety. JBT Foodtech is setting a more stringent temperature reduction to 45°F.

The objective of this project is to redesign the batter coolant system on the ProMix continuous batter mixer in order to reduce the temperature of the mix 10°F in 20 minutes and then maintain a temperature between 40 and 45°F in order to ensure compliance with FDA/USDA regulations.

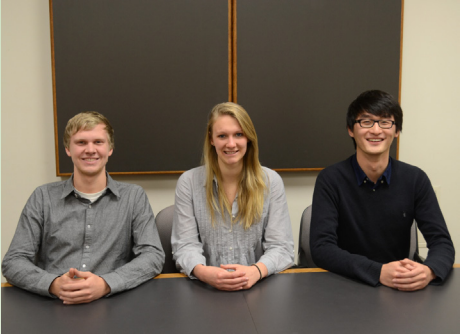


(B to F, L to R) Michael O'Meara, Lucas Poquette, Adrienne Bunce & Stacey Stark

Emission Mitigation From Confined Animal Feeding Operations (CAFO) Using Wet Scrubbers And An Algae Culture

Animal feeding operations emit large quantities of ammonia gas and particulate matter. These emissions affect the health of workers and residents in the surrounding area. Without emission mitigation animal feeding operations will not be able to continue to expand with growing demand for meat and dairy products.

To design an integrated wet scrubber system which will show-er ventilation exhaust air and absorb the ammonia and particulate matter. The effluent water will be used in an algal cultivation greenhouse system to recycle the water, while developing value-added products from the algae, such as fertilizer.



(L to R) Benjamin Thomas, Elyse Kutsche & Yingkui Zhong

Torrefaction Process Improvement

Typical torrefaction product yields are approximately 70%; however, HTI experiences a low product yield of 30% for their torrefaction process. Large particle size distribution and large variance in the shape of wood chips make it difficult to ensure complete biomass torrefaction.

Green Coal, Inc. will design a method to increase the product yield of HTI's torrefaction process while consistently and completely torrefying biomass of varying size and shape.

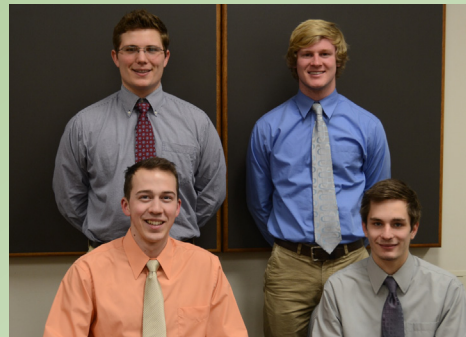


(L to R) Kristen Henn, Jamie Yeung, Kaitlin Ward & Jinsha Li

Chestnut Chip Dehydration System Design

Chestnut chips are a value-added product that can be used as an ingredient, eaten as a snack, or milled into flour. In order to realize the market potential of chestnut chips, chip drying techniques must be investigated and optimized to make the production of chestnut chips economical.

By determining the theoretical drying parameters, investigating alternative systems, and performing economic analyses, the optimal dehydration system for chestnut chips can be determined. A tool must be developed that determines the optimal dehydration system parameters.



(B to F; L to R) Kyle McLachlan, James Burns, Ethan Nussdorfer & Jacob StLouis

Water Quality Best Management Practices Design for a City of Lansing Re-Development Project

Urban landscapes have a high percentage of impervious areas increasing stormwater runoff times and peak flow conditions. Using best management practices from the Michigan Low Impact Development (LID) Manual, runoff can be managed to reduce the quantity and improve the quality of the stormwater.

To design an efficient stormwater runoff treatment system for the redevelopment of a parking lot in downtown Lansing in compliance with Michigan LID techniques.



(L to R) Joshua Wolter, Matthew Herman & Maureen Berryman

Integration of Aquaculture, Anaerobic Digestion, and Hydroponic Systems

Currently, aquaculture is expensive and has a long payback period after an initial capital investment. Incorporating aquaculture with anaerobic digestion and hydroponics adds an additional source of revenue to the system along with the reduction of operational costs through the combustion of gas produced from an anaerobic digester.

Optimize an anaerobic digestion system using fish carcass and wastewater from an existing aquaculture facility, with the products from the anaerobic digester used as fertilizer and an energy source to maximize yield in a hydroponic system.



(L to R) Derek Hladki, Kristin Sanburn & Nathan Janderno

Hydroponic Processing Optimization for Mung Bean Sprouts

Mung beans are grown hydroponically from seed to sprout in 5.5 days where they are used in La Choy products by ConAgra. The process has not been modified in over four decades and observable losses in yield and sprout quality are evident.

The goal of this project is to increase profit by optimizing the hydroponic system and reducing a 3% loss of quantity due to hard bean germination and a 10% loss due to water shortages. Multiple production processes are being investigated including pH imbalance which causes browning, lowering the quality of their product.

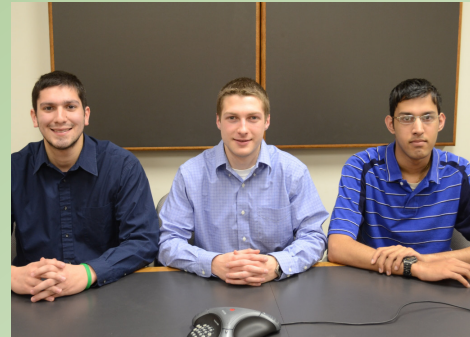


(B to F, L to R) Kelsey Downey, Ander Rochefort, Sarah Steudle & Maddie Saylor

Dried Blood Spots Optimization for DNA Extraction

The Dried Blood Spot (DBS) technique is an effective way to screen for diseases and genetic disorders for patients who do not have much blood to give, access to veins to draw blood such as infants and the elderly, and also for those who live in low resource areas.

Improvement of the method can make blood testing more efficient and much more cost effective. The project goal is to increase the yield of DNA that can be extracted from a DBS sample in the most cost effective and time-efficient manner.

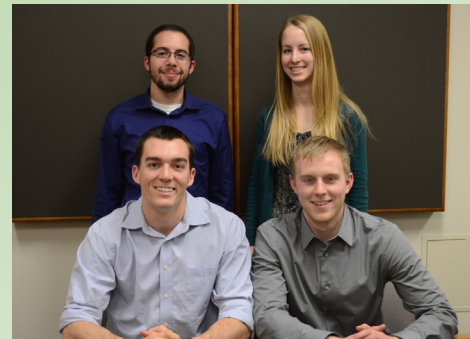


(L to R) Kayvon Parvizi, Steven Archer & Kunal Choubey

Optimization and Modeling of a Plastic Bottle Rinser

The bottle rinser is the last step in decontamination before the product is hot-filled into the containers. When the bottle rinser operates optimally, the risk of public safety or fiscal loss due to microbial or foreign material contamination is significantly reduced.

Design a process to reduce microbial contamination and reduce foreign materials in the packaging bottles before the bottles reach the hot-fill beverage lines at the Ocean Spray juice factory.

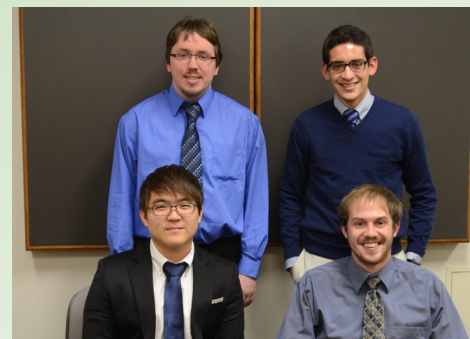


(B to F, L to R) Paul Zeltzer, Jena Laur, Tyler White & Matthew Crowder

Electrocoagulation-Flotation Treatment System for Anaerobic Digestion Effluent

Conventional chemical and physical treatments of agricultural, municipal and industrial residual waste streams do not provide an efficient solution with a small footprint and limited chemical utilization. This presents the need for a cost-effective, high strength water treatment and reclamation system.

The goal of this project is to investigate the effectiveness of coupling dissolved air flotation and electrocoagulation-flotation technologies in treating liquid AD effluent to improve upon the efficiency of the processes when utilized independently and to recover nutrients.



(B to F, L to R) Robert McGuire, Ryan Gardner, Younsuk Dong & Luke DeSmet

International Reflections

A year with the MSU BAE study abroad programs

➤ From Costa Rica

As outlined in the 2012 annual review, the Michigan State University (MSU) Department of Biosystems and Agriculture Engineering (BAE) launched an “Ecological Engineering in the Tropics” program to Costa Rica in collaboration with University of Costa Rica (UCR) College of Biosystems Engineering (BE) colleagues. The program ran from December 15-29, 2012. The inaugural program was very successful with nine MSU BAE students, one Oregon State ecological engineering senior and five UCR biosystems engineering and agronomy students participating. MSU coordinating faculty members included BAE colleagues Dawn Reinhold and Luke Reese, along with UCR colleagues and UCR Department of Biosystems Engineering Chairperson Jose Francisco Aguilar, engineer Jose P. Rojas and Fabio Research Station Manager Werner Rodriguez. We studied and traveled together for a rich cultural immersion on a UCR mini-bus with stops at the Organization of Tropic Studies, La Selva; Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE), Turrialba; Corbana Banana Cooperative, La Rita; ICE, Tilaran; Universidad EARTH La Flor, Liberia; University of Georgia Monte Verde; and the University of Costa Rica facilities, to name a few. We integrated cultural visits during visits to production and processing facilities for bananas, coffee and rice. The first day of the program began with a student presentation session and interaction at Fabio Baudrit Experiment Station, Alajuela. UCR and MSU students presented their academic work, which was interspersed with a picnic lunch and a challenge soccer game.

The Costa Rica program utilized the facilities constructed through a U.S. Department of State clean energy and water grant as an experiential learning laboratory. Students learned about anaerobic digestion and treatment wetland designs for producing green energy and clean water. Students then formed teams to design, construct, plant and launch floating mats for the treatment wetlands. Mat design specifications included: 1) floating with the total weight of the growth media and fully mature plants; 2) allowing for easy harvest of mature biomass; 3) constructing with common, available, local materials; and 4) constructing cheaply.



After two weeks of designing, specifying materials, learning about Costa Rican plant biodiversity, selecting plants and constructing and testing flotation worthiness, student teams planted and launched their floating mat designs. Photos were taken at the Fabio Baudrit Experiment Station.



Students learned many lessons as they designed four unique mats. Students were expected to:

- understand major themes related to clean energy, water and climate and the interactions among these systems in Costa Rica as compared to the United States;
- understand and calculate carbon, energy and water footprints for commonly consumed foods such as bananas, coffee and rice;
- develop their critical, creative, design and reflective thinking skills related to clean energy, climate, water and ecosystem services; and
- enhance their ability to interact with cultural differences, understand issues of socio-economic equity, and consider issues from diverse perspectives for engineering designs and installations.

For a comprehensive look at the daily program and student learning activities, please review the program blog at: <http://cr2012studyabroad.wordpress.com/>.

To “Down Under”

Jim Lucas, MSU Office of the Associate Provost for Undergraduate Education, and Luke Reese co-instructed the 2013 Australia Food, Environment and Social Systems program that extensively studied human impacts on the environment/ecosystems. This program catered to a broad range of majors and sought to help students explore broad questions related to sustainability. Through targeted site visits, lectures, course readings, analytical essays and a personal research project, students connected their learning experiences back to their lives as students, future professionals, engineers, scholars and citizens. The 2013 program ran from May 11 - June 8 and 24 students participated. Students addressed questions such as:

- What is sustainability? How can it be defined and measured?
- How do social and economic issues influence humans' interactions with their environments?
- What are our personal and collective responsibilities toward promoting sustainability?
- What happens when you do not have enough potable water, and how do you address that issue?

For a comprehensive look at the daily program and student learning activities, please review the program blog at: <http://aussie2013studyabroad.wordpress.com/>.



Students perform an erosion control service project to help understand the complexity of environmental issues and alternatives. Photo was taken at the Calperum & Taylorville Stations, Australian Landscape Trust, in Renmark, South Australia.



Above: Students take a bike tour on one of the five enclosed relocated rubbish mounts in Sydney Olympic Park. The park is a recovered brownfield site where all surface runoff water is retained on-site. The former Olympic Village, which is now condominiums, completely recycles wastewater within 24 hours of being flushed for use in showers, toilet flushing, irrigation, landscape fountains, laundry, car washing, etc.

Left: Students participating in study abroad to Australia before bioenergy lecture at University of Adelaide.

Study abroad transforms students' lives

Studying abroad takes the student out of their comfort zone and forces critical thinking. Even if traveling to an English-speaking country, the culture, context, diction and customs are different, forcing students to think outside their shells. While it usually takes time to sink in, students return from study abroad as global citizens putting things more in the context of the whole versus the individual. Engineers use ideas, expertise, materials, designs, equipment, parts and supplies from around the world. By default, engineers require international knowledge and savvy.

BE students can have international learning experiences without crossing international borders. International experience and sharing can occur within the confines of Farrall Hall. Over two-thirds of the BE graduate student demographics for fall 2013 is international. BAE has graduate students from China, Colombia, Costa Rica, India, Iran, Iraq, Korea, Mexico, Nepal, Thailand and Vietnam. In addition, BAE has undergraduate students from China, Korea and Japan. BAE welcomes all international experiences as enrichment to our classes, students and ultimately global citizenship.

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A gift to the MSU BAE Department is an investment in future generations for the environment, food safety and the planet.

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