Greetings from Agricultural and Biological Engineering

Welcome to the latest issue of ABE@Illinois, which focuses on water and the global environment. Luna Leopold, a leading U.S. geomorphologist and hydrologist, has said, “Water is the most critical resource issue of our lifetime and our children’s lifetime. The health of our waters is the principal measure of how we live on the land.”

In these pages, you will read about examples of ABE teaching, research, and outreach activities that address this critical resource issue of water. They begin with teaching students from across the campus about the importance of water in a global context through ABE 199: Water and the Global Environment. ABE’s global outreach efforts span many parts of the world, as reflected in the descriptions of projects in Honduras and Sierra Leone that address rural community needs for the supply of water.

Water issues also apply in the urban context, and ABE researchers Paul Davidson and Lu-Ming Chen are studying experimental permeable water pavements that help with drainage. Research by Yuehui Zhang addresses the challenge of separating wastewater from different sources, such as humans, animals, and plants, and growing algae in that wastewater as a method of removing excess nutrients and capturing carbon dioxide. The algae is then harvested and converted into a fuel source.

We are able to leverage our research farm not only to carry out research, but also to provide demonstration facilities—for example, with short courses offered regularly to personnel from the Illinois Department of Transportation, who take care of the state’s roads, including designing and building them to include adequate drainage.

This suite of articles is a sample of the many water-related efforts of our faculty, students and alumni. Please enjoy the articles, and let us know your thoughts. We would love to hear from you.

Best regards,
Alan Hansen, Interim Head

Water and the Global Environment

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Technology doesn’t exist in a vacuum, and that’s a concept that students face head-on when they enroll in Engineering 440: International Water Project.

Ann-Perry Witmer, an instructor in the Department of Agricultural and Biological Engineering, has taught the course for six years. She co-teaches the class with ABIE Ph.D. candidate Kevin Jahner. The class, which spans two semesters, can be a student’s first exposure to contextual engineering, a new area of the discipline that investigates the relationship between technical design and non-engineering considerations like politics, culture, and economics. “Contextual engineering merges engineering with the social sciences. It requires an engineer to learn the needs that are unique to a client from the client’s perspective before trying to address them,” says Witmer.

Each year’s 20 to 30 students enrolled in ENG 440 spend the year designing the technical, social, and political aspects of a water distribution system for a village in another country. The course challenges many of them, Witmer says, in requiring serious self-reflection.

“To understand the client’s perspective, students first have to recognize their own reasons for doing things and to build an understanding of how people in their client community are different from—and similar to—them,” says Witmer. “This can be a painful process because it calls into question a lot of the assumptions of engineers—mainly that we’re the experts and we know better than anyone else what should be done.”

Because the course is multidisciplinary, only about half of the students are engineers. “Students from other disciplines come into the course a little terrified that they’re not going to be able to contribute, and the engineers come in thinking they’re in charge,” says Witmer. “They spend a lot of time the first semester connecting those assumptions. It can get stressful for everyone,” Witmer points out with a smile. “That’s why we started using alumni mentors. Alumni who made it through a previous class volunteer to work with the current students and help them through the process. They’re able to say, ‘I got through it and so will you. Just ride it out and it will make sense.’”

Witmer says a second tier of mentors is equally important. “Rather than trying to know everything about everything, students need to identify expertise. So we have professional advisors who are practitioners in areas that are not engineering but are related to the course, such as community health, sociology, and translation studies.”

Witmer brings the mentors to the classroom, but it is up to the students to figure out how to use them, she says. “One of the most important goals of this course is to help students understand how things are done in real-life engineering. I was a consultant for water systems for more than a decade. No consultant is ever going to hand you a list of problems to solve, or say, ‘Do these calculations and everything will work.’ A lot of the job is figuring out how to work with the consultant to identify the problem. So we bring the mentors to the classroom and have them talk to the students, but the students have to take it from there.”

Students also must define and organize the teams they will need within the course to design the water system. “Because Engineering 440 takes all levels of students as well as all disciplines,” Witmer says, “we have Ph.D.’s and we have freshmen. So students are given enough structure to make sure their teams are diverse—because we don’t want a graduate team or an engineering team or a political science team—but they need to figure out what the needs are and how they want to divide themselves.”

At the semester break, Witmer travels with about 15 students to the community where the water system will be installed. The goal is to immerse the students for 10 days to learn as much as they can about the community’s culture and needs.

“Students aren’t allowed to stay in nice hotels,” Witmer explains. “Everyone brings sleeping bags and mattress pads to use in space we rent from the village. We live with community members, and we hire people from the community to cook meals for us so that we eat what they eat. We interview locals, and the information we gather enables us to better understand their values and their expectations. The most technologically advanced infrastructure isn’t sustainable if it can’t coexist with a community’s value system.”

As an example, she talks about an experience the class had two years earlier in Honduras, with a community identified with the Lenca sect of the Mayans. “The Lenca have a very strong spiritual connection to the earth. At one point, the leader of the community took us to see some very special springs, called ‘ojos’ or ‘eyes.’ The water was beautiful, and we told the community we could build a catch bin and put a pump in it to keep it in Context

“We interview locals, and the information we gather enables us to better understand their values and their expectations. The most technologically advanced infrastructure isn’t sustainable if it can’t coexist with a community’s value system.”

Julissa Nunez, a student in ENG 440, focused her design work in Honduras on facilities at a local elementary school. The school has only one simple pila, so Julissa worked with professional advisors to create a full lavamano (handwashing station), latrines and showers that will be constructed for the students and teachers.
and that those springs could serve the community for many years to come.”

When the leader learned that a catch bin, used to keep bacteria out of the water, was a concrete box, into which a tap empties, “we couldn’t put concrete around those springs, because they were the passageway to the afterlife,” says Witmer. “Covering them with concrete would prevent passage and condemn everyone in that community to walk the earth for eternity. If we had built a concrete box over those sacred springs, the community would have broken the box and taken it away.”

When the students return from their immersion trips, they use the information they’ve gathered to do complete engineering designs for the water system — by hand as opposed to using any design software. “If we created them the way we do in the U.S., no one would know how to read them,” says Witmer. “We put the designs through a full-quality-control evaluation by professional engineers before we give them back to the community for their final approval.”

Of the six ENG 440 classes, the water systems designed by the first three have been completed, and construction for the fourth is underway. Projects usually require $15,000 to $20,000. A group of Rotary clubs in Florida, which Witmer has worked with for many years, raises the funds. “Our most recent project was with Llano Largo and San Antonio, Honduras, two communities who partnered on their water system,” says Witmer. “Construction will probably start in the fall of 2019 and be completed in the spring of 2020.”

Meanwhile, Witmer is working with students in her sixth class on projects in Honduras and Guatemala, the first time the class has worked in two countries at once. “As gratifying as it is to bring clean water to communities in need, Witmer knows that many students believe they have gained more from their experience than they’ve given. “It’s transformative,” says Witmer. “And that’s their word, not mine. It’s not easy to step back from your own values and expectations and look at someone’s life and needs through a different filter. When you do, it’s transformative.”

Akelos works to enhance development success

Kelsey Schreiber, a graduate student in AB E, is president of Akelos, a nonprofit start-up that “helps existing international water projects create community-specific solutions” around the world.

Schreiber and a group of colleagues recognized the need for this work after their participation in ENG 440, International Water Project. “Aimed with a critical perspective from that course, we recognized the shortcomings of development work,” says Schreiber, “and we wanted to create a nonprofit that challenged the status quo of international water projects.”

S chreiber notes that there is no shortage of organizations that pursue development initiatives in countries outside the U.S., but the field is plagued with stories of failure, a disheartening reminder that not all good intentions lead to success. “This comes as no surprise,” says Schreiber, “because it is inherently difficult to work on international development projects. Such projects force us outside of our familiar cultural and political contexts, and they require us to navigate the often-conflicting objectives of the stakeholders.”

Schreiber says when failure occurs, it inevitably happens at this gap in communication. “For example, the technical achievements of an outside group of engineers are often disconnected from the local reality of the problem, or the funding requirements are completely mismatched with the priorities of the community.”

So Akelos focuses its efforts on connection, communication, and collaboration. “We work as consultants for our partners—other nonprofit organizations with existing water projects—by applying our experience and insight where our partners most need the assistance.”

The organization has worked in Guatemala, Honduras, and Senegal, on projects with vast differences that required unique approaches. “What’s interesting is how different the way nonprofits manage their projects and their resources by helping to facilitate conversations,” Schreiber concludes. “We provide technical assistance when necessary, and we emphasize the importance of working together with the community we serve.”

Katie Flahive

Katie Flahive, B.S. ‘99 AgE – Keeping the states “in shape”

For a runner, Washington, D.C. is a great backdrop for marathon training,” says Katie Flahive, an environmental scientist at the U.S. Environmental Protection Agency. “In addition to running, Flahive says, she tries to spend time on the Appalachian Trail, and she makes frequent visits to the Shenandoah National Park. "I love to spend time in the kitchen cooking and baking. Though her hobbies are an antidote to spending the workday at a desk, Flahive enjoys that work as much as her off-hour activities.

"I support states in their efforts to reduce water pollution from nonpoint sources, with a focus on reducing nutrient losses from agricultural lands in the Mississippi River Basin," she says. “I gauge the progress we make toward reaching challenging water quality goals, and I work with faculty in agronomy and water disciplines across the Midwest to understand the state of the art and apply it to EPA programs as well as to collaborate with other federal and state programs.”

Flahive came to Illinois as a freshman and transferred to the Department of Agricultural Engineering at the start of her sophomore year. A dean in the College of Engineering brought her to AEBS to meet some faculty members and ultimately helped her make the decision to transfer. After her first two ag engineering classes, Flahive says, it was clear she had made the right decision.

"I was pleased to find an engineering major in the environmental sciences that was not all about the built environment and how to better amend it," says Flahive. "To me, ag engineering is about enhancing the natural features in the built environment and maximizing this integration to use but also protect and restore water and soil resources.”

In fact, Flahive says, that might be one of the greatest challenges facing ag engineers today. "It’s equally art and science to strike the balance of a robust agricultural economy and healthy water resources. This department is important as ag engineers are creating the tools we need to ensure that these resources will be protected and restored for generations to come.”

The challenge is one that Flahive seems to relish. "I hear new ideas and I work to make them accessible to those looking to innovate and solve complex problems. I may sit in an office in Washington, D.C., but I have many opportunities to engage with creative thinkers with open minds through workshops and other means of applying knowledge to reality. It’s invigorating.”

Jennifer (Wolf) Delpierre

Jennifer (Wolf) Delpierre, B.S. ’06 TSM – Family and Farm

Jennifer Delpierre is a soil conservationist with USDA-NRCS in Knox County, but the young mother is also a farmer, a seamstress, and a former rugby player.

"I think it’s important to take advantage of as many opportunities as you can and broaden your horizons,” says Delpierre. "Those opportunities give you great experiences from which to learn, to develop as a person, and to build your career.”

Delpierre has a lifelong history with agriculture and a family history with the University of Illinois. “I knew I wanted to be an ag teacher or work in soil conservation,” she says. "My ag teacher and FFA sparked my interest in being a teacher, and the family farm and my dad’s involvement in the tiling business got me interested in soil conservation.”

An uncle, two aunts, and a cousin are all Illinois alumni, and Illinois was the only college to which Delpierre applied. She began her studies in agricultural engineering, but after a summer internship with a soil and water conservation district in the office of the Natural Resources Conservation Service, "I learned I didn’t have to have an engineering degree to design waterways and dry dams, so I switched to technical systems management.”

During her college years Delpierre served an internship with Hancock County’s Soil and Water Conservation District, where she evaluated CRP (Conservation Reserve Program) contract compliance in the field and did some survey and design work on general practices. In a second internship with Illinois Extension in Knox and Rock Island counties, she assisted with educational programs and developed a community garden.

Timothy Darm s

Timothy Darm s – P.E., B.S./11 ABE – Joyfully Obligated

For Tim Darm s, it’s just not possible to separate his work as an engineer from his Christian faith. "I feel joyfully obligated to use the gifts and skills God has given me for His glory," says Darm s.

Darm s is the senior project engineer in the Innovation Department at Water Mission, a nonprofit Christian engineering organization based in North Charleston, South Carolina. Water Mission designs, builds, and implements safe water, sanitation, and hygiene solutions for people in developing countries and disaster areas.

Darm s came to Illinois from Harper College, a community college in Palatine, Illinois. "I did two years at Harper, and it was one of the best decisions I ever made. I saved tens of thousands of dollars, and I was more than academically prepared to transfer to Illinois.

"Illinois is one of the best engineering schools in the nation," says Darm s, and ABE provided me a broad engineering education. The foundations in hydraulics, groundwater, electricity, and other areas set me up well for my job. My engineering degree had direct application to helping people overseas. And maybe most importantly, I learned how to learn, and how to enjoy learning.”

As senior project engineer for Water Mission, Darm s works on an array of projects, including developing off-grid solar water systems, automating the data collection process, and remotely monitoring system performance.

"In the nonprofit world, it’s difficult to monitor system performance after implementation," says Darm s, "so we continue to develop our remote monitoring capabilities. These include monitoring of daily water production and groundwater depth, pressure, turbidity, and ORP."

"There is great satisfaction for him in this mission field," says Darm s. "The work is challenging; I have to continue to learn to be successful at what I do. And, ultimately, our work at Water Mission glorifies God. I consider this to be my ‘95%’ dream job,” he concludes. "The missing 5% would have me doing this while being overseas myself.”

A college highlight for Delpierre was studying abroad in Stuttgart, Germany, the summer of 2006.

"I took a three-week course on agriculture economics, and I had a room in a retired professor’s home. My living arrangements immersed me in the culture of Germany off campus, and my memories of local people and places are too many to count. My one regret is that I didn’t take the opportunity to study abroad for an entire semester.”

Today, a typical day on the job can include work with three different financial assistance programs along with conservation compliance. "CRP EQIP (the Environmental Quality Incentives Program), and CSP (the Conservation Stewardship Program) are voluntary programs that offer financial assistance to producers to install conservation practices to improve their farming operations.

"I enjoy helping farmers conserve the land that we have,” Delpierre says. “It takes a long time for soil to form, but it can be so easily washed away in a single storm event.”

Delpierre farms with her husband, Jayson; they have a small cattle operation. Time with her children includes playing, running, or biking outside, sewing, reading Fancy Nancy to her four-year-old daughter, Jadyn, and truck books with her one-year-old son, Beau. "I only reading these days involves children’s books, but any reading with my kids is always worthwhile.”
The need to understand and appreciate the world’s largest natural resource—water—is deepening every day. One course in ABE addresses the impact of water availability and quality on the daily lives of people around the globe.

“Water is our most precious resource,” says Prasanta Kalita, professor in ABE and one of three instructors for ABE 199: Water in the Global Environment. Rabin Bhattarai and Paul Davidson, also professors in ABE, co-teach the class.

Although papers and exams are part of the course, Kalita doesn’t believe traditional evaluation methods are necessarily the best. “CHP students are the best of the best,” says Kalita. “There is no possibility that these kids are going to fail, so along with exams, we ask them to pursue a topic that can express their creativity.”

Last year, the instructors received a request from a professional society for student videos dealing with the value of water. “The Environmental Engineering and Science Foundation sponsored a national competition to increase awareness about the stewardship of water,” says Kalita. “We had four teams enter the competition; one placed first and another third. It was very gratifying to see the teams’ hard work recognized in that way. [The videos are available for viewing at http://www.eesfoundation.org/student-video-competition.]”

“Water quality and its effect on the global environment is one of today’s most important and critical areas of worldwide concern,” Kalita says. “We want our students to use the knowledge they gain in this class to make an impact both locally and globally.”

“It’s my dream to see ABE 199 offered across campus,” he says. “We’d hold it in Foellinger Auditorium and have 700 students. That’s a big class, but I don’t know how I would manage it, but I have to dream.”
P3 studies pavement options for stormwater management

Permeable pavement is a common best management practice recommended for stormwater management in urban areas. A new study—the Permeable Pavement Project, known as P3—examines several pavement systems to gauge their ability to adapt to a variety of environmental conditions. The study is being conducted by Paul Davidson, a professor in ABE, and Lu-Ming Chen, an ABE postdoctoral research associate.

Three types of paving materials have been installed at the ABE Farm Research and Training Center in south Urbana. The first is conventional impermeable concrete, which is found in most parking lots. The second is pervious concrete, a porous surface that is usually not recommended for high-volume and heavy-loading roads. If the surface is not maintained properly, solid materials may clog the pavement pores and reduce the retention rate of the permeability over time.

A third material is the JW Eco-Technology, invented and patented by Jui-Wen Chen, president of Ding-Tai Co. Ltd. in Taiwan. “We chose this product because it is a permeable pavement, has the potential to support heavy loads, and has never been used in the United States,” says Lu-Ming Chen.

“The structure is an imbedded plastic aqueduct,” Davidson explains. “It’s a frame you snap together that covers the whole area you want to pave. You pour standard impermeable concrete inside this frame, and it fills in all the gaps. Once it dries, you pull the caps off of small holes that allow the water to infiltrate.”

P3 uses nine paving pads, each 20 feet by 10 feet, to mimic the size of a one-car driveway. Three of the pads are conventional concrete, three are pervious concrete, and three are the JW Eco-Technology system. All the pads are orientated north to south with a two percent slope, allowing surface water to drain into the water collection system. The pits attached to the pavement pads are equipped with tanks and barrels to collect both surface and subsurface runoff. By collecting surface runoff and subsurface runoff separately, the researchers can assess the ability of each pavement system to reduce surface runoff.

“The overall goal of P3 is to investigate the environmental adapting capacity of the different pavement systems,” says Chen. “The distinct weather differences in the four seasons in Illinois allow us to investigate and compare the effects and functions of different pavements in different seasons.”

“We’re conducting several experiments,” says Davidson. “First we’ll study the hydrological performance of the different pavements. If water infiltrates the permeable pavement faster, it should be able to reduce flooding and surface runoff.

Second, we’re looking at the water-quality benefits of permeable pavements,” he says. “When water infiltrates that type of pavement, it then goes through the underlying soil. Soil typically acts as a very good filter, so we’re going to try to determine if different contaminants are mitigated by different pavements.”

A third experiment will study the permeable pavements’ ability to improve air quality by diluting pollutants emitted from cars parked on the pads. “There is an exchange of air between the pavement and the soil, so we want to see if the pavements can capture and sequester some of the exhaust gases,” says Davidson. “Gaskets around the cars will keep the gases in, and instruments will monitor the concentrations of different gases.”

A fourth experiment will look at winter performance of the different pavements. “Because of the exchange of air between the pavement and the soil,” says Chen, “warm air coming up from the soil could in theory affect snow melt and reduce snow accumulation. Each of the nine pads is equipped with sensors to continuously monitor the temperature on the pavement surface and a few feet above the pavement surface. “Here in Illinois temperature might not have a big impact, since we can get a lot of snow,” says Davidson. “But in areas of Taiwan where they get only small amounts of snow, the temperature difference might be enough to affect plowing and salting roads.”

The JW Eco-Technology system being tested has been installed in China and Taiwan, but the demonstration site in south Urbana is the only one in the United States. Jui-Wen Chen [the inventor of the technology] flew here to help install the pavement,” says Davidson. “His quality control is very high, and he wanted to make sure the system was installed according to his design. Installation is a little more labor intensive, but if the benefits outweigh the labor, the system could definitively be worth the investment.”

JW Eco-Technology provided the material and consultation required for the company’s pavement, and the research team will be allowed to use this patented product until October of 2020. A consortium of private companies in Taiwan is currently funding the P3 research.
The Department of Agricultural and Biological Engineering has long been a leader in the research areas of water quality, management, conservation, and distribution. Much of that work is done at the ABE Research and Training Center, an extensive off-campus facility in south Urbana that provides a comprehensive platform for a variety of research projects. More commonly referred to as “the farm,” the facility provides 70 acres currently divided into 15 separate plots. Plot size ranges from two to eight acres, and can be reconfigured to suit research needs. The farm can also access land from other groups for larger projects: they currently use 40 acres from animal sciences.

The permeable pavement project (see “P3 studies pavement options for stormwater management,” page 10) is only one of several water research projects at the farm. It is also home to the Erosion Control Research and Training Center. The site contains an earthen berm 300 feet long and 13 feet high, and three ditches with check dams at the base of the berm that drain into a small pond. ABE professors Prasanta Kalita and Robin Bhattacharyya research and evaluate products used for erosion and sediment control, and they provide training in erosion and sediment control best practices for the State of Illinois Department of Transportation employees and engineering professionals.

Another project studies tile drainage through bioreactors. Richard Cooke, ABE professor and drainage extension specialist, has equipped three separate plot fields with field tile that is directed through a wood chip bioreactor. Water quality samples are taken at various points as the water travels through the bioreactor in an effort to determine materials and characteristics that provide the highest removal of contaminants from the outgoing water.

Laura Christianson, an assistant professor in crop sciences, also studies drain water management at the farm, using monitoring wells placed around two different fields. A different management style is used on the two fields to evaluate how water and nitrates seep out of each. In addition to these water research projects, other projects include:

- A multi-year study to investigate the effect of tire pressure and tillage depth on crop development, soil and water conditions, energy requirements, and farming economics. (Dr. Tony Griff – ABE)
- The efficacy of proprietary insecticides to control western corn rootworm. The impact on the root system is evaluated with techniques developed at Illinois. (Dr. Joe Spencer, Dr. Nicholas Sisler – Crop Sciences)
- Multiple tillage treatment plots contain replicated tillage regimens. ABE students and staff have conducted grain yields and soil compaction evaluations annually since 1999.
- An environmental research facility for poultry focuses on improving animal husbandry, primarily for commercial agriculture and research laboratory settings. (Dr. Angela Green-Miller – ABE)
- A study of residue management, weed control and seedbed preparation with the Kelly Tillage System. (Dr. Tony Griff, Jake Niehaus – ABE)
- A study of acoustical soil sensing. (Dr. Tony Griff, Brendan Kuhns – ABE)

ABE farm provides platform for water research—and much more

We want our students to have the best learning experience possible, and the farm is one of our greatest resources.”

Tim Lecher, manager of the facility, has been with the department since 2014. “This is an excellent research facility,” says Lecher; “but there’s so much more that we offer. Al Hansen and Tony Griff [professors in ABE] teach classes that give students an overview of agricultural machinery and off-road equipment, and we have a fleet of equipment from a number of industry equipment manufacturers. John Deere has been very generous to us, and we have equipment from Case IH, New Holland, and DMi as well.”

Lecher says they have conducted farm tours for different manufacturing and industry groups, including an international engineering group from John Deere Worldwide Crop Harvesting Product Development. These were people in leadership who research and develop John Deere combines, and they were from Deere centers in Illinois, Germany and Brazil.

Lecher said the farm is also home to the Solar Decathlon House, a solar home developed in part by students in ABE who participated in the Solar Decathlon in 2011, a biennial competition sponsored by the U.S. Department of Energy.

Student clubs who use the farm include the Illini Pullers and the Mini-Baha SAE. These teams design and build quarter-scale tractors and off-road vehicles for national competitions. They have a test track area at the farm to develop and test their equipment prior to competitions.

“We’re always looking for research opportunities and support in order to keep our equipment and the facility current,” Lecher concludes. “We want our students to have the best learning experience possible, and the farm is one of our greatest resources—for anyone interested in ag and bio engineering.”
A project that began in 2013 to harvest rainwater in Sierra Leone is making a significant impact on rice and sweet potato crops there. Richard Cooke, professor and drainage extension specialist in the Department of Agricultural and Biological Engineering, works with colleagues at Njala University to design rainwater-harvesting systems that increase agricultural productivity in the country’s inland valley swamps and uplands.

During Sierra Leone’s rainy season, which lasts from May through November, the country can receive up to 80 inches of rainfall. But, Cooke says, there is no national strategy for collecting the surplus rain to use during the dry season.

“The rice grown in the swamp is NERICA (New Rice for Africa) 19, a variety developed for African conditions. ‘High-yielding Asian varieties were crossed with disease-resistant African varieties. The growing season is about 90 to 100 days—a short crop. After harvest, we plant rice again. We harvest the second crop of rice, then we plant legumes.’

Farmers in Sierra Leone normally grow one rice crop per year. “With our system” says Cooke, “we can grow three crops every year—two rice and one legume.”

One of our projects is in the lowest area of the Njala University inland valley swamp. We built a berm across half of the swamp,” says Cooke. “It’s basically a dam with a reservoir behind it. We collect the surplus rainfall to use for irrigation during the dry season. An outlet structure in the dam regulates the movement of water.”

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The researchers have found that the yield in the dry season is higher than the yield in the wet season, Cooke says, and more than twice the national average. The reason? “There is more sunlight, more direct solar radiation, so there are higher yields. We also add bio-char to the soil, so there is some organic matter that allows the soil to hold more water.”

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There is a critical need for research that enables new means of adapting society’s consumption of food, energy, and water, especially dealing with its biowaste. Yuanhui Zhang, a professor in ABE, is conducting research that uses these biowaste to produce bioenergy and food, reuse wastewater, and capture carbon.

In collaboration with other researchers across the UI campus, Zhang is developing a novel paradigm called EE-FEW S—Environment-Enhancing Food, Energy and Water Systems—to process biowaste.

“The United States produces 79 million dry tons of biowaste annually from animal manure and food processing alone,” says Zhang. “It’s typically been considered a burden instead of a resource.” One of the biggest problems in extracting energy from biowaste is its high water content. Often more energy is required to dry it as can be extracted from it.

EE-FEW S works by using hydrothermal liquefaction (HTL) to convert the wet waste without drying HTL uses water as the reaction medium; it mimics the natural process of forming fossil fuels, but it reduces geologic time scales to less than an hour. HTL produces biocrude by separating hydrocarbon compounds from nutrients in the biowaste system.

Fast-growing algae are cultivated in the wastewaters from the original liquid waste stream and the HTL effluent, which is sterile and free of microbial activity. Algae uptake a portion of the excess nutrients and capture carbon dioxide. The resulting treated wastewater is used for vegetable production, and the algal biomass is fed back to the HTL process for conversion of additional biocrude, which allows for multicycle reuse of nutrients and carbon dioxide that can be added to the biowaste stream.

“We have proven by our own lab experiments that the EE-FEW S paradigm can reuse nutrients three times,” says Zhang, “and simulations have shown it might be possible to reuse nutrients 10 times. The amount of biocrude is amplified by the same factor.”

Because biocrude production and nutrient use efficiency are dramatically increased, wastewater is treated and reused; food is produced at much reduced need for chemical fertilizer or water, and carbon is captured to a level of net-zero emission. In addition, Zhang says, the EE-FEW S paradigm can be transferred to other sectors, such as municipality biowaste.

Zhang’s team includes ABE graduate students Aersi Aierzhati, Michael Stablein, Megan Srbodila, and Jamison Watson. The team is working on constructing a pilot-scale HTL reactor that is mounted on a mobile trailer. The reactor will have the capacity to process one ton of biowaste and produce 30 gallons of biocrude per day.

The students will also produce a video that documents this research. “The National Science Foundation has a program, INFEW S [Innovations at the Nexus of Food, Energy, and Water Systems], to fund discoveries that promote understanding of the interactions between the systems of food, energy, and water,” Zhang says. “They have asked us to produce a video of our work that they will feature on their website.”

In his most recent project, Zhang led a team to research and produce renewable engine fuels (upgraded from HTL biocrude oil) that would be compatible with the existing diesel fuel infrastructure. Their paper, “Renewable Diesel Blendstocks Produced by Hydrothermal Liquefaction of Wet Biowaste,” was published in the journal Nature Sustainability in November 2018. The first author of the paper was Wan-Ting (Grace) Chen, a former graduate student of Dr. Zhang and now a professor at the University of Massachusetts - Lowell.

MechS E  graduate student Timothy Lee is leading the engine tests. Other contributors were Zhenwei Wu, Buchun Si, Alice Lin, and Brajendra K. Shama.

“Because of the increasing complexity we find in each of these systems, this research must be multidisciplinary.” says Zhang. “A single discipline can’t handle all of these systems alone. But agricultural and biological engineering is involved in all of these systems at some level, and we are positioned to take a leadership role in this research.”
This is a sample of the permeable pavement technology, JW Eco-Technology, invented and patented by Jui-Wen Chen, president of Ding-Tai Co. Ltd. in Taiwan.