SPRING 2019

CIVIL AND ENVIRONMENTAL ENGINEERING

UNIVERSITY OF WISCONSIN-MADISON

PLANNING THE AUTOMATED ROADS OF THE FUTURE

CHAIR'S MESSAGE

Greetings from Madison!

It's an exciting time in CEE. *U.S. News & World Report* ranked us 15th nationally among undergraduate civil engineering programs and 11th among public civil engineering programs in its 2019 list, up three spots from the previous edition! More and more colleagues at our peer institutions are discovering our faculty's great scholarship all around the world.

In January 2019, we welcomed our 34th faculty member. Along with our 30 adjunct faculty members and our first faculty associate, our department is now the largest and most diverse we've ever been!

Our undergraduate enrollment has grown considerably over the past five years, and we're making steady progress in attracting a more diverse student body. These ambitious students are learning that civil and environmental engineering goes beyond designing and building our nation's infrastructure. They're developing evergreen problem-solving skills that will allow them to be outstanding civil, environmental and geological engineers with the leadership and entrepreneurial skills to flourish across any industry.

Alumni support is crucial to creating a dynamic educational experience. I'm pleased to report our total dollars raised grew 24 percent in 2018, with 15 percent more alumni supporting our efforts. This kind of gift support allows us to send students to competitions and conferences, bring leading scholars and events to campus, recruit and retain faculty, and provide the teaching and research infrastructure befitting a world-class university. Thank you to all of our alumni and friends who supported us this past year.

We're about to see a concrete result of some of that support: Our new structures research facility, the Jun and Sandra Lee Wisconsin Structures and Materials Testing Laboratory, will be completed in a matter of weeks. The expanded lab, built thanks to the backing of alumni and friends, will allow faculty and students to conduct full-scale testing of structural elements and materials. Having such a facility reinvigorates our historic strength in structural engineering.

Stay connected to us on the web (**www.cee.wisc.edu**) and on Facebook and Twitter (**@UWMadisonCEE** on both) for updates throughout the year. If you're looking for an excuse to make it back to Madison, put our annual CEE Golf Outing on your calendar for September 20, 2019.

ON, WISCONSIN!

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Benchtop bioreactors contain conversion residue from lignocellulosic ethanol production. *Photo: Great Lakes Bioenergy Research Center.*

Pushing microbes to deliver preferred products

If Wisconsin Distinguished Professor Daniel Noguera had his way, he would orchestrate a microbiome to pump out higher-value chemical products.

In that vein, Noguera, along with graduate student Matt Scarborough and collaborators in the Great Lakes Bioenergy Research Center at UW-Madison, published a paper in the journal *mSystems* in which they analyzed the makeup and metabolic activity of a mixed microbial community within a bioreactor. By doing so, they're edging closer toward engineering such a community to optimally generate particular products, an outcome that would boost the utility—and financial viability—of the residue of biofuel production.

In their work, the researchers studied the organic leftovers of lignocellulosic ethanol production with an eye toward optimizing the yield of medium-chain fatty acids, which are useful precursors for industrial chemicals and pharmaceuticals. The medium-chain fatty acids are an alternative product—with a higher potential financial value—than the methane that's typically generated from the residues of ethanol production.

"If we think about the residues from that process and generate more value from those residues, the hope is that we improve the economy of the overall system," says Noguera.

The researchers identified the members of the microbiome and their roles in the process, while using thermodynamic analysis to examine potential ways to drive production of the medium-chain fatty acids.

"We can establish communities that make these materials, but the ratio of medium-chain fatty acids to other microbial products is not optimized," says Noguera. "So how do you get the microbes to change? Or how do you engineer that community to make more of what you want? That's still an open-ended question."

ENERGIZING IMPACT:
CAPSTONE STUDENTS DESIGN SUSTAINABLE SYSTEM FOR RURAL SCHOOL

In the tiny unincorporated burg of Juda, Wisconsin—population 357—there's a clear community centerpiece.

"If you want to know what the trick-or-treating hours are, you call the school," says Scott Anderson, a high school math and engineering teacher at Juda School, a building that houses roughly 300 students from 4K to grade 12.

So any project touching the school is apt to attract interest in this community that sits 6 miles north of the Wisconsin-Illinois border—an enthusiasm that was readily apparent to a group of senior capstone design students during the fall 2018 semester.

As part of UW-Madison's UniverCity Year partnership with Green County, the team proposed a renewable energy system to help offset Juda School's energy expenses by 25 percent.

Community members watched the students' presentation on YouTube. The Badger engineers also did a radio interview about the project with a station in nearby Monroe.

"They're really proud of their school," senior Morgan Keck says. "They're really excited about our project, so I think that's something that's made it more real for us and better than designing something for a private company where it's more about profit. They're truly excited about showcasing whatever we design."

An aerial view of Juda School in rural Green County. The building houses all of the district's students from 4K through high school. *Photo: Juda School District.*

Each semester, students tackle projects for clients that range from private companies to state agencies and other public entities. Adjunct faculty members and team mentors who are also practicing engineers lend advice on tactical elements like putting together proposals, delivering presentations, project management and estimating costs. Then it's up to the students to deliver a detailed solution—giving them a taste of the kind of work they'll face after graduation.

Keck and fellow seniors Connor Acker, Emma Connell, Brooke Marten and Robin Ritchey analyzed possible renewable energy systems for Juda School from five perspectives: environmental impact, safety, constructability, financial cost and social considerations.

They looked at systems used at schools across the state, as well as one in Laramie, Wyoming, and consulted with topic experts like their team mentor Casey Joyce, a project manager at solar energy contractor SunPeak, and Associate Professor James Tinjum, who has extensive experience with wind turbines.

All that research and analysis pointed to a system that incorporated both a geothermal heating and cooling system and a rooftop solar panel array.

"It's given me confidence that I could go work on something that I've never really experienced before and be able to learn it quickly," says Ritchey.

Visits to Juda also allowed the UW-Madison engineers to connect with the nine students in Anderson's class and show them both a tangible example of engineering work and a viable path from a high school of less than 100 students to a university with more than 40,000.

"It shows them the opportunities that are out there in the world," Anderson says. "It's a great motivator for my students."

Assistant Professor Andrea Hicks' *Environmental Sustainability Engineering* class also worked with the Juda students to compare the environmental, economic and societal impacts of solar and wind energy systems at the school.

UW-Madison engineering students (far right, clockwise) Brooke Marten, Robin Ritchey, Emma Connell, Morgan Keck and Connor Acker pose with team mentor Casey Joyce (middle), Juda High School teacher Scott Anderson (front) and his students outside of Juda School. *Photo: Scott Anderson.*

MORE: www.engr.wisc.edu/energizing-impact-uw-madison-engineering-students-design-sustainable-system-rural-school/

Photos: Sarah Page

BUILDING A FANTASY FACTORY

Construction alum hops into brewery

Zak Koga's baseball dreams were fading as he rode home to Appleton, Wisconsin, in the passenger seat of his dad's Mercury Sable in 2004. His one year of Big Ten baseball at the University of Iowa was mercifully over, doomed from the start after the coach who had recruited him resigned.

Father and son talked about the 19-year-old's options as they drove northeast on U.S. Highway 151 toward Madison. Despite Koga's baseball predicament, he had aced his classes as an engineering major. On a whim, they decided to stop at the Red Gym to see if a transfer to UW-Madison might be an option.

A few months later, Koga (BS '08) returned to campus for the start of the fall semester.

"It was one of the best things I ever did, making that decision," he says while sitting in the taproom at Karben4 Brewing, the popular brewery he co-owns on Madison's northeast side.

After graduating from UW-Madison with a degree in civil engineering and an emphasis in construction engineering and management, Koga carved out a steady career at the construction firm Findorff, first as a project engineer and then a project manager.

On the side, he had also begun helping his older brother Ryan, then the head brewer at a brewery in Montana, pursue his own operation in Madison. While hatching plans with Ryan and longtime friend Alex Evans, Koga came to a realization: He wanted more from his career than simply to work his way up in the construction industry.

Although Koga stuck with his day job after Karben4 launched in 2012 in the former Ale Asylum brewery building, the birth of his first child in 2014 gave him the nudge he needed to make the full-time career jump.

> **"You are trained to be a very competent problem solver. It's breaking things down into little parts, solving the parts and putting them together."**

At that point, Karben4 had gained a following, largely on the strength of its India pale ale Fantasy Factory, but it wasn't yet bottling its brews.

"We needed to be moving faster. It wasn't sustainable to stay where we were," recalls Koga. "It became very clear: We needed to move faster here. We needed to grow. We couldn't do that if we didn't have more resources. We needed more time as a group."

These days, Karben4 bottles its six flagship beers, along with a variety of seasonal offerings. Production has increased from 700 barrels in 2013 to about 11,200 in 2018, even as the beer market has grown increasingly saturated.

Koga, who oversees the company's finances and operations, says his engineering education permeates his job, whether he's analyzing Karben4's supply chain or helping install a new bottle labeler.

"It's constant. It's problem-solving. That's most of what engineering is, right? You are trained to be a very competent problem solver," he says. "It's breaking things down into little parts, solving the parts and putting them together."

The box for Karben4's amber ale, Block Party, includes images of the Red Gym and Máquina, the fountain sculpture on Engineering Mall. They're nods to the two serendipitous campus stops Koga and his dad made on their drive back to Wisconsin in 2004, the day that launched his odyssey in Madison.

"Looking back, it only feels disjointed and meandering when I talk about it. When I think about it, it makes perfect sense," he says. "Growth requires pain. Things get a little messy and they're tough. But that's the whole thing. The process of facing the world and deciding to do the right thing—as best as you can decipher it—that's our existence."

RAN PLOTS ALTERNATIVE PATH TO TRANSPORTATION AUTOMATION

Bin Ran dreams of a day when a trip from Madison, Wisconsin, to Chicago's O'Hare Airport includes a nap behind the wheel.

Ran, a Vilas Distinguished Achievement Professor, has been working to turn that dream into a reality for the past two decades, though not in the way you might think. Ran's vision isn't based on the kind of autonomous vehicles being developed by the likes of Google's Waymo, Uber and Tesla—supremely modified cars capable of making most driving decisions on their own.

Instead, Ran is among the transportation researchers championing an alternative approach: Rather than placing the technological onus solely on the vehicle, outfit the road with the hardware that allows less complex vehicles to work together with the infrastructure.

"We make the highway—the road—smart, as well," says Ran, who calls this approach connected automated vehicle and highway.

Ran, who co-directs the Traffic Operations and Safety (TOPS) Laboratory at UW-Madison, believes there are multiple benefits to this method. Moving most of the sensing and computing equipment to the roadside significantly reduces the cost of an individual connected vehicle and makes it a more economically viable option for a larger swath of the population. He also says roadways can accommodate more sensors, allowing for greater overall vision. And if cars don't have to carry supercomputers, they'll consume less power and generate less heat.

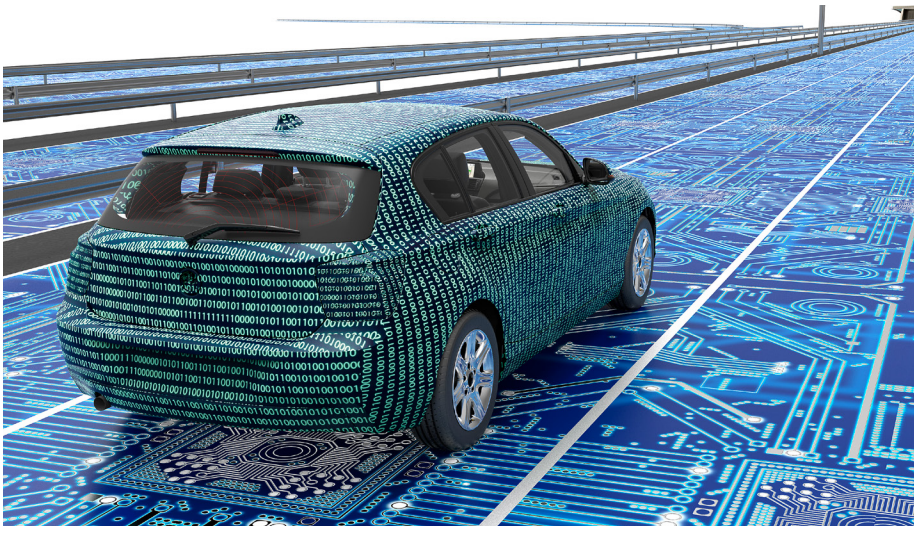
"We can make the car very lightweight and cheap enough, and then we put lots of devices on the road," he says, using an analogy of a car as a phone and the infrastructure as a server.

The idea of an automated highway actually dates back to the early 1990s, when the U.S. Intermodal Surface Transportation Efficiency Act allocated federal funds for research on the topic.

In 1997, the National Automated Highway System Consortium, a coalition of industry partners and researchers that included Ran, held a demonstration of the results near San Diego. Over the course of four days, a fleet of vehicles—enhanced with radars and computers—drove along a strip of Interstate 15 that researchers equipped with guidance magnets.

But the work fizzled, and the idea of individual autonomous vehicles has drawn more interest—and funding—in the decades since.

Ran has continued working on different components of a connected system since "Demo '97," before turning his attention to pulling them all together in recent years. He has partnered with collaborators at China's Southeast University, using a test site—a stretch of open road in the city of Nanjing—and a driving simulator. It's part of the UW-Madison and Southeast University Joint Research Institute on Internet of Mobility, which launched in late 2017. Southeast's School of Transportation is the top-ranked program in China, according to Ran, who's leading the joint research institute.



The driving simulator at Southeast University.

UW-Madison representatives at the launch of the UW-Madison and Southeast University Joint Research Institute on Internet of Mobility in China in 2017. From left: David Noyce, Ian Robertson, Shanglu He, Jeff Russell and Bin Ran.

Big-picture progress on autonomous vehicles continues to creep forward; for example, Waymo launched a small fleet of self-driving taxis in a few Phoenix suburbs in December 2018, but CEO John Krafcik has cautioned that autonomous cars won't be ubiquitous for decades.

Ran has yet to publicly unveil his work, but he's hopeful the technology can reach commercialization in the next few years.

When it does, Ran believes it will make our roads safer. A National Highway Traffic Safety Administration survey cited human error as the cause of 94 percent of car accidents in the United States—and making vehicles and roadways work in concert might be the path to improvement.

"We can cut that down by at least half or more. Safety is definitely the top priority," he says, noting that TOPS Laboratory research assistant Wenxin Huai was killed in a traffic accident in April 2017. "We hope our work can prevent that tragedy from happening again in the future."

SONE LENDS EXPERTISE TO RECORD-BREAKING DRILLING EXPEDITION

Lingering motion sickness is one of the occupational hazards of working at sea off the coast of Japan for weeks at a time. Assistant Professor Hiroki Sone can attest to that, having spent parts of the 2018-19 academic year on the deepest scientific oceanic drilling project ever.

Sone and PhD student Zirou Jin were part of the international team of scientists working on the Nankai Trough Seismogenic Zone Experiment. In the final phase of the 11-year experiment, researchers drilled below the Nankai Trough, the meeting point of the Eurasian and Philippine Sea tectonic plates and the source of repeated earthquakes.

Assistant Professor Hiroki Sone stands on the drilling vessel Chikyu's heliport.

"To be directly in there and see the material improves our understanding of what is actually happening."

The drilling, which reached a record depth of 3,058.5 meters below seafloor (more than 10,000 feet) in early December 2018 and continued until March 2019, yielded rock samples and allowed the team to install sensors, potentially unearthing new clues about the processes that drive earthquakes.

"We want to understand what kind of forces are accumulating in this plate boundary, because that's the driving force for ground motion during earthquakes," says Sone. "To be directly in there and see the material really improves our understanding of what is actually happening."

Sone led the group's physical properties team, which examined the rock debris generated during drilling, calculating changes in porosity, the percentage of empty space in the rock that's filled by water. Porosity typically decreases with depth, but the researchers looked for exceptions to that trend that might indicate higher-than-expected fluid pressure.

Sone hopes to take rock core samples from the plate interface and slowly deform them in the lab, part of an effort to better understand the forces that build up during the 100 to 400 years between the earthquakes that generate tsunamis in the Nankai Trough.

"It's important to understand how the earth ruptures during these large earthquakes that happen in a matter of minutes, and scientists have focused on that for many decades," he says. "But what happens in between the 100 years? How does the force accumulate to get ready for the next earthquake? That is an equally, if not more important question to ask that we have not addressed in the community. We'd like to make a breakthrough there to better forecast seismic hazards around the world."

MORE: **www.engr.wisc.edu/drilling-deep-clues-earthquakes/**

Bahia's research paves way for greener asphalt

When construction workers rip up a road, they're not simply tossing aside garbage. Asphalt, even after being battered by heavy trucks, stretched and compressed by the weather, and cooked by the sun, remains recyclable—offering environmental and financial benefits to state departments of transportation.

Yet, according to a report from the National Asphalt Pavement Association, the average percentage of reclaimed pavement in new asphalt mixtures nationwide in 2017 was just 20.1 percent.

Vilas Distinguished Professor Hussain Bahia hopes to increase that number. His lab, the Modified Asphalt Research Center, is working on an 18-month project with the Recycled Materials Resource Center to performance test asphalt mixes using 30- and 50-percent recycled content. By defining the properties that affect performance and establishing more effective testing methods, his group hopes to pave the way for wider adoption of asphalt containing higher levels of recycled content.

"There are a lot of ideas of how to estimate the effect of these recycled materials without testing the full, final product," says Bahia, whose lab is an international leader in research on additives, substances that enhance raw asphalt to improve on-road performance. "We're trying to do more than that. We will be testing the final product."

Bahia's group will test different rejuvenating oils, which restore aged asphalt's flexibility, and alternative methods of applying them to asphalt.

The end goal: provide agencies and industry players with tests and standards that ensure recycled mixes perform as well as or better than conventional mixes.

Read more about Bahia's research and sustainable asphalt: **www.engr.wisc.edu/road-greener-asphalt/**

SWISS SABBATICAL OPENS NEW OPPORTUNITIES

Sure, Associate Professor Christy Remucal misses seeing her students and colleagues on a daily basis. And she had to cope with a winter without much snow or frozen lakes.

But there are some perks to spending the 2018-19 academic year in Zurich, Switzerland.

"We live a 10-minute walk away from the train station," says Remucal, who's on sabbatical leave. "You get on a train, you ride a gondola, you go hiking."

Of course, exploring the Swiss Alps is only a small portion of Remucal's stay in Zurich. Remucal, who studies water quality, is using the time abroad to build new research collaborations while splitting the year between two respected institutions: ETH Zurich, where she previously spent three years as a postdoctoral associate, and Eawag (the Swiss Federal Institute of Aquatic Science and Technology).

Christy Remucal takes a break from sledding at Mount Pilatus.

"Switzerland, and Zurich specifically, has some of the best water research going on in the world," says Remucal.

At ETH, Remucal is working with Professor Kristopher McNeill and Senior Scientist Michael Sander to study dissolved organic matter, which can cause chemicals in water to degrade. While Remucal's research group at UW-Madison generally uses high-resolution mass spectrometry and ultraviolet-visible spectroscopy to measure the reactivity of dissolved organic matter, Sander employs an electrochemical-based technique.

During the second half of the year, Remucal has collaborated with Professor Urs Von Gunten, a leading expert on the use of ozone for disinfecting drinking water, a tactic used more widely in Europe than the United States. Disinfectants are crucial to killing off pathogens in water, but they can also react with dissolved organic matter to produce harmful byproducts. Remucal will examine how ozone reacts with dissolved organic matter.

In between working in the lab, writing research proposals and giving seminar talks, she's still meeting weekly with her six PhD students via video conferencing.

Remucal says her experience in Zurich will lead to further research opportunities after she returns to Madison. She's also using the time away to plot new directions, such as looking at perfluorinated chemicals, a type of contaminant that's increasingly showing up in Wisconsin.

DEPARTMENT NEWS

Assistant Professor and Charles G. Salmon Fellow of Structural Engineering **Pavana Prabhakar** won a 2019 Young Investigator Award from the Office of Naval Research. Prabhakar's project aims to facilitate the design of lightweight structural materials to improve damage tolerance and resilience under extreme loading and environmental conditions in vessels, offshore structures, aircrafts and automobiles. Her work could help prevent catastrophic structural failures.

Professor **Steven Loheide** received a UW-Madison Vilas Mid-Career Investigator Award in recognition of research and teaching excellence. The award provides flexible funding over two years.

PhD student **Madeleine Mathews** received a Wisconsin Distinguished Graduate Fellowship through the UW-Madison Graduate School, while master's student **Amy Plechacek** landed a National Science Foundation Graduate Research Fellowship. Both work in the lab of Assistant Professor Matthew Ginder-Vogel.

Associate Professor **Soyoung Ahn**, Assistant Scientist **Madhav Chitturi** and Arthur F. Hawnn Professor **David Noyce** are collaborators on a $924,000 grant from the U.S. Department of Transportation's Federal Highway Administration. The project, led by Assistant Professor of Electrical and Computer Engineering Kassem Fawaz, aims to create a mobile warning system to prevent collisions between vehicles and bikers or pedestrians.

Geological engineering master's student **Morgan Sanger** received an Early Excellence in Teaching Award as part of UW-Madison's 2018 Campus-Wide Teaching Assistant Awards. Sanger has taught *Soil Mechanics and Problem Solving Using Computer Tools*.

Professor of Practice **Charles Quagliana** won the James G. Woodburn Award for Excellence in Undergraduate Teaching as part of the college's annual faculty and staff awards.

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FROM THE ARCHIVES: OFF TO SUMMER CAMP

Back in 1926, when this photo was taken, civil engineering students were required to complete a summer surveying camp to earn their degrees. The six-week camp, held in a few locations around the state of Wisconsin, covered topographic and land surveying, as well as route location for railroads.

In 1962, the department broadened the camp to include general civil engineering material (and highway location instead of railroads). When the department adopted a new curriculum in 1973, it stopped offering the camp.

Today's civil and environmental engineering students gain practical experience in a whole host of ways: senior capstone course projects, summer internships and co-ops, on-campus research positions and more.

Read more about one senior capstone project on page 3.

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