UNIVERSITY OF WISCONSIN–MADISON
COLLEGE OF ENGINEERING

2022

PERSPECTIVE

LOOKING FORWARD

We are uncovering solutions to global challenges while equipping students with skills to soar

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PERSPECTIVE
MAGAZINE

ENGINEERING EXTERNAL RELATIONS

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A MESSAGE FROM DEAN IAN ROBERTSON

Greetings from Wisconsin!

The United States has long been recognized for its leadership in developing and applying new technologies. This leadership has been vital to our economic development and our national security. However, numerous recent reports have indicated that our country has been losing ground, or has already ceded leadership, in key technological areas such as artificial intelligence, 5G infrastructure, quantum information science, and green energy technologies, to Europe and Asia. While the trend is alarming, it is possible for us to reestablish our leadership position in key technologies through strategic investments.

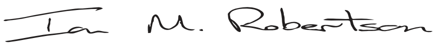
Top engineering colleges like ours can and should play a central role in leading the rebuilding efforts. Among our initiatives in the College of Engineering are hiring at least 25 faculty in specific areas, including autonomous systems and robotics, advanced materials and manufacturing, and energy systems; planning for a new $300 million engineering facility that will provide our faculty, staff and students with advanced instructional and research spaces; planning workshops in specific technologies; and increasing the number of opportunities for students to become Badger engineers.

And while our college is known for its excellence in fundamental research, we're also pursuing several initiatives to provide our faculty, staff and students exposure to, training in and support for entrepreneurial activities. Part of this effort involves creating—in partnership with the College of Letters and Science and the School of Computer, Data and Information Sciences—the Technology Entrepreneurship Office. This office will provide not only instruction on how to drive a great idea from concept to commercialization, it also will provide our faculty, staff and students with the "end-to-end" support—for example, identifying funding opportunities, technology transfer resources through the Wisconsin Alumni Research Foundation, connections to Badger entrepreneurs and industry leaders, and more—that they need to succeed as entrepreneurs. We will be calling on you to assist in making this effort a success.

We're also expanding our connections with industry through our Office of Corporate Relations. One notable effort includes a unique collaboration with the strategic operating capital firm WISC Partners (co-founded by engineering alum Mike Splinter and business alum David Guinther). Our collaboration with WISC Partners provides our engineering faculty the opportunity to perform service as consultants with high-potential technology companies. If you are interested in sponsoring research or having one of your research staff spend a year on "sabbatical" in our college, let us know, as we want to expand our engagement with industry. You can contact me or Russ Johnson, who leads our Office of Corporate Relations.

One of UW-Madison's longest and deepest traditions is known as the Wisconsin Idea—a commitment to public service and the principle that education should influence people's lives beyond the boundaries of the classroom. As engineers, this is exactly what we do. And we're redoubling our efforts to ensure that our innovations—as well as our human capital—play a leading role in keeping our nation competitive, healthy, safe and secure.

On, Wisconsin!



Ian Robertson
Grainger Dean of the College of Engineering

Dedicated to fostering the highest standards of integrity, ethics, inclusiveness, and service to society.

Our college's research priorities include:

- **Energy, sustainability and the environment**
- **Intelligent systems and communication**
- **Advanced materials, design and manufacturing**
- **Engineering healthcare**

We've also articulated two themes that cut across our priority areas and enable us to conduct research more effectively and efficiently:

- **Computing and data-driven engineering**
- **Advanced sensing, analysis and characterization**

PROGRESS ON THE PATH TO FUSION

BY TOM ZIEMER

NEW TECHNOLOGIES AND AN INFLUX OF PRIVATE INVESTMENT ARE SPARKING DEVELOPMENTS IN A FIELD THAT SEEKS TO REALIZE A LONGSTANDING ENERGY DREAM.

The lithium in your laptop battery could be converted into fusion fuel that could power the city of Madison, Wisconsin, for a year.

Professor David Anderson likes to point that out to his students to grab their attention. It's the kind of grand promise that makes fusion energy sound so tantalizing, particularly in the context of our ongoing struggles to slow the warming effects of climate change. Fusion, the process that powers the sun, generates no greenhouse gases and only minimal nuclear waste.

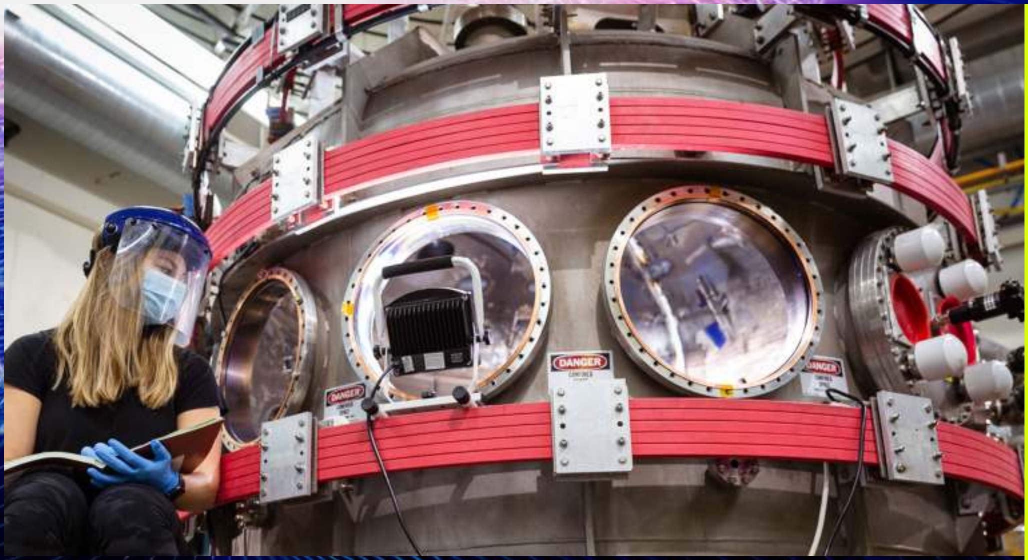
And while renewable energy sources such as solar and wind can supply a growing portion of the energy we need to replace fossil fuels, they occupy large amounts of land, are dependent on weather, and simply can't provide the necessary baseload power to meet large-scale consumption.

Fusion can. It also avoids the safety and waste concerns associated with nuclear fission.

"It's the energy of the stars. It's the energy of the future," says Anderson, the Jim and Anne Sorden Professor of electrical and computer engineering and one of the scientists who's helped establish UW-Madison as a longstanding U.S. leader among universities that conduct fusion and plasma physics research. "Limitless power."

But, as you might expect, fusing atomic nuclei by heating hydrogen isotopes—ideally deuterium culled from seawater and the less-abundant tritium generated from lithium—to hundreds of millions of degrees and safely containing the resulting plasma (ionized gas) is a Herculean task.

Scientists began to study the fundamental physics behind fusion in the 1920s and started creating experimental reactors in the late 1940s. While the sun relies on gravity to confine its plasma, most earthbound efforts employ magnetic fields to do it. That's how the colossal fusion experiment ITER (the largest magnetic plasma confinement device ever built) will work upon its completion in southern France, with a target date of 2027 for running its first plasma.

Carolyn Schaefer, a PhD student in engineering physics, works on the Pegasus-III fusion experiment.

ITER is the result of an unprecedented and complicated international collaboration and investment of, officially, $22 billion, with an equally audacious aim for a field seeking progress toward viability: to produce more power than it consumes, something for which no previous fusion reactor has been specifically designed. In the process, ITER will allow researchers to study "burning plasma" that relies more on self-sustaining internal fusion reactions than on external energy fed into the system.

While that milestone is at least a decade and a half away, there are more immediate developments that stoke optimism in researchers like Oliver Schmitz, the Thomas and Suzanne Werner Professor of engineering physics and the college's associate dean for research.

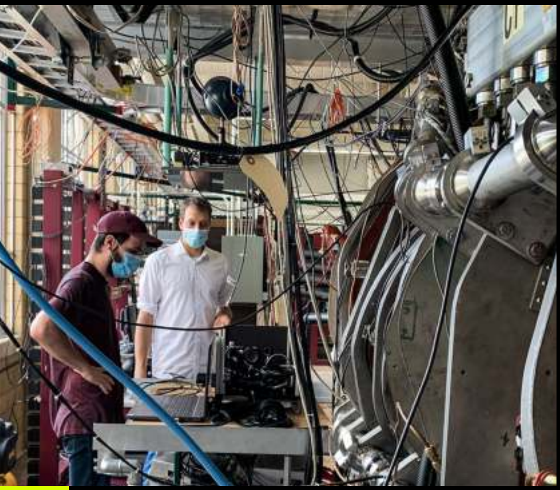
"I'm more hopeful than ever that it will work out," says Schmitz, who leads research projects focused on the interactions between high-temperature plasmas and reactor walls at several international fusion facilities.

In September 2021, researchers at Massachusetts Institute of Technology (MIT) and the spinoff company Commonwealth Fusion Systems (CFS) broke a magnetic field strength record in demonstrating their high-temperature superconducting electromagnets, which could make more compact—and, thus, more economically viable—fusion reactors a possibility. The new magnets are the centerpiece of the SPARC reactor, a joint MIT and CFS effort to surpass that break-even net-energy barrier by 2025.

Advances in supercomputing and in plasma theory and modeling in recent decades have sharpened researchers' ability to optimize experimental reactor designs, and the emergence of additive and advanced manufacturing open up new possibilities for quickly prototyping and precisely producing components for reactors.

"We finally have all these advanced tools, all at the same time," says Engineering Physics Assistant Professor Stephanie Diem, rattling off the aforementioned technological breakthroughs along with advances in alloys and materials for reactor walls. Diem directs the Pegasus-III fusion and plasma science experiment at UW-Madison. "There's been a convergence of a lot of things in recent years that makes fusion energy more achievable in our near future."

The field also has more money flowing into it, with private equity firms entering the fray. While publicly funded national and international facilities have historically driven the field forward, startups like CFS, General Fusion and TAE Technologies are now aggressively chasing their own timelines to satisfy their investors. At least 35 fusion companies exist worldwide, boasting combined financial backings in the billions of dollars.



Engineering Physics Assistant Professor Benedikt Geiger (right) and physics PhD student Ryan Albosta work on the Helically Symmetric eXperiment (HSX), which is housed in the Department of Electrical and Computer Engineering.

Anderson is a founder of one of those startups, along with Chris Hegna, the Harvey D. Spangler Professor of engineering physics and an expert in theoretical plasma physics and computational modeling. Their Type One Energy Group hopes to bring a large-scale fusion reactor to the Madison area, building upon lessons from the Helically Symmetric eXperiment (HSX) in Engineering Hall.

The lion's share of fusion experiments around the world are devices called tokamaks, powered by most of the fusion research funding since the Soviet scientists made breakthroughs with the donut-shaped reactor in the late 1960s. ITER is a tokamak, and that reactor class is the consensus pick to achieve viable fusion energy output first. The new Pegasus-III in the basement of the Engineering Research Building is a spherical tokamak, a more compact design that resembles a cored apple and allows for more efficient use of its magnetic field to confine plasma. Diem and her team will test innovative plasma startup techniques on Pegasus-III that could reduce the cost and complexity of future fusion reactors.

HSX, directed by Anderson, is an example of a stellarator, the leading alternative to the tokamak. Rather than driving current through the plasma to confine it as tokamaks do, stellarators rely on twisted electromagnetic coils around the outside of the vessel to create magnetic fields—in theory, sacrificing design simplicity and inherent symmetry for the ability to precisely control the plasma physics externally. Results from HSX have demonstrated the value of using plasma theory and modeling to dictate coil design, making it either the world's first or second optimized stellarator, depending upon who you ask (some reserve that honor for Wendelstein 7-X in Germany, the world's largest stellarator).

Now, Anderson and Hegna want to apply optimization at a larger scale, coupled with advanced manufacturing capabilities and CFS magnets. "The explicit goal is to make stellarator fusion work," says Hegna.

While Type One is still courting investors, another type of fusion reactor—representing more immediate possibilities within the field beyond energy production—is under construction at UW-Madison's Physical Sciences Laboratory in nearby Stoughton. The Wisconsin HTS Axisymmetric Mirror (WHAM), led by Physics Professor Cary Forest, with support from Schmitz, is reviving a "mirror" reactor design that researchers largely abandoned in the 1990s. Leveraging the high magnetic fields available through advances in high-temperature superconductivity, the mirror path and much simpler cylindrical fusion reactors they embody again appear feasible. WHAM, which will be the first to take advantage of these technologies, will focus on efficiently producing the neutrons generated in fusion reactions.

Those high-energy neutrons, in turn, can be used to manufacture isotopes with a range of medical applications, from diagnostic scans to treatments, as well as other imaging tools. That's precisely how SHINE, the Janesville, Wisconsin-based company founded by three-time alumnus Greg Piefer (BSEE '99, MSNEEP '04, PhDNEEP/MedPhys '06), is applying fusion technology. To Schmitz, SHINE embodies the current opportunity available with fusion, regardless of its transformative potential in the energy sector. It's why he, Forest and others at UW-Madison are pursuing funding to support fusion industry development—through education and technology—in southern Wisconsin.

"Fusion is happening now," says Schmitz. "The opportunity for building industry and a workforce and educating technology leaders is now, and not in 10 or 15 years, because people think fusion is 30 years down the road. Workforce readiness is key to drive the technology innovation underlying a future fusion industry."

POWER TO THE PEOPLE

Three ways our nation's electrical grid must change for a brighter future

By Jason Daley

The world is on the cusp of a renewable energy tipping point; with recent technology advances, green energy generation methods like solar and wind are on the rise.

That's great news for efforts to slow climate change and decarbonize the energy sector. But in the United States, our aging and outdated energy grid—including 200,000 miles of high-voltage interstate transmission lines and 5.5 million miles of local distribution lines—could be a roadblock in that transition.

To meet that demand, the energy grid needs some big improvements to shuttle electrons from industrial-scale solar and wind farms to factories and cities across the country. That's why researchers in the College of Engineering are thinking about solutions that will make the system more stable, robust and ready for next-generation power.

1

Missing connections

One of the biggest improvements the grid needs is more interconnection. Currently, the U.S. power grid is really three separate grids—one connecting the states east of the Rocky Mountains, a solo grid for the state of Texas, and another grid for the West Coast. By connecting these grids, explains Electrical and Computer Engineering Assistant Professor Dominic Gross, it would be possible to take advantage of time differences to optimize renewable energy. “Let’s say you’re producing a lot of solar power in California in the afternoon, when no one is home to use it,” he says. “That would coincide with the demand peak on the East Coast. However, we have no means to shift the power there. Instead, we have to try to store it and use it locally.”

Interconnection also means that if weather or other issues take down the grid in one area of the country, it would be possible to send backup power from unaffected areas. For instance, in February 2021, when severe winter storms in Texas caused the grid to fail for several days, leading to hundreds of deaths, it would have been possible to provide residents with electricity by shifting energy from the eastern or western grid if those networks had been linked.

There are a couple of ways to connect the grids. One option is high-voltage direct-current transmission lines, sometimes called electrical superhighways, that can shuttle energy thousands of miles without too much energy loss. That technology already is in wide use in Europe.

But Electrical and Computer Engineering Professor Giri Venkataramanan, who directs the college’s Wisconsin Electric Machines and Power Electronic Consortium, and Electrical and Computer Engineering Assistant Professor Line Roald are currently researching low-frequency alternating-current systems, which could use the existing infrastructure and may perform just as well as their direct-current counterparts, but at a much lower cost. Either way, tying the grid together is one of the best ways to maximize renewable energy.

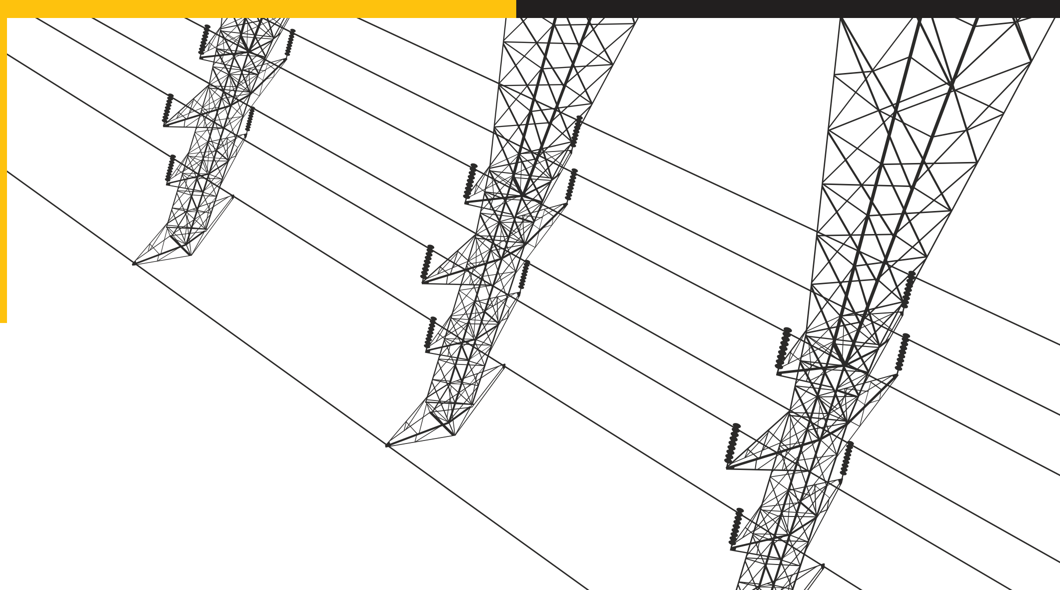
2

Future proof

When energy travels through those long interstate transmission lines, it is “stepped down” and arrives at home appliances like your Instant Pot via a massive web of distribution lines, usually run by local utility companies or governments. This network could use a major upgrade as well.

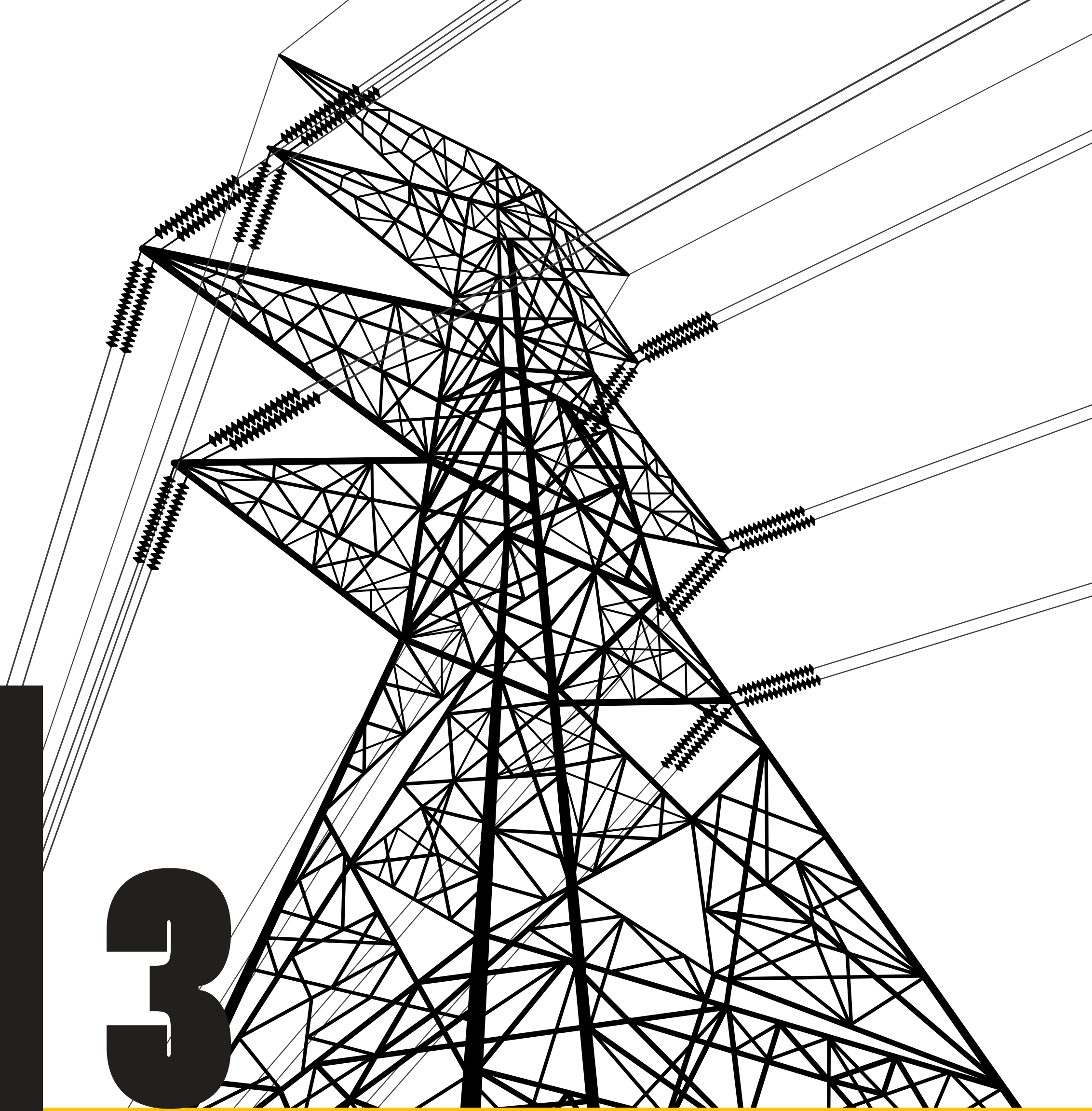
Roald works on finding ways to optimize these distribution lines. She says the most important task for local line operators is preparing the system for climate change. “We have an increased incidence of severe weather; we have heat waves and sometimes we have cold spells that are expected to become more severe and more frequent,” she says. “So we have to make everything work together through that.”

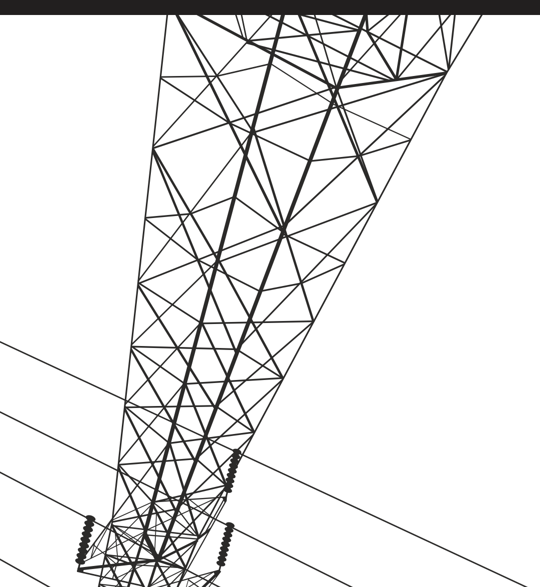
Changes will need to take place on the local level, with utilities burying power lines susceptible to high wind or



overhanging vegetation and replacing old or worn-out infrastructure. At the same time, they'll need to implement smart grid technologies, such as switches that allow utilities to turn off certain distribution lines or reroute power when trouble does occur.

In her research, Roald creates tools that help utilities analyze their grids and prioritize their resources, helping them to make the most cost-effective, wide-reaching changes first. "The grid does need money devoted to it," she says. "It needs repairs and maintenance. But the most important thing is when lines are destroyed by major weather events, we shouldn't just rebuild them as is. We need to focus on upgrading lines so they can fare better the next time around."





3

Smart ideas

In the future, the grid won't just rely on large-scale utilities for its upkeep; smart technologies on the consumer side will also contribute to grid optimization and stability. Gross, for instance, is part of a new $25 million universal interoperability for grid-forming inverters consortium. In the "legacy" way of making power, huge generators like coal plants produce a frequency and signal that other producers can use as reference. A grid full of thousands of decentralized renewables, however, doesn't have a source to lock onto, and could result in unstable and erratic power. Gross and others in the consortium are working on ways to develop and use inverters that allow renewables to form their own frequency—independent of legacy power plants.

Venkataramanan says that in the coming decades, the devices and gadgets in our homes will also play an important part in optimizing and stabilizing the grid. Smart technologies will allow car chargers, appliances and large energy users like water heaters and air conditioners to ramp their energy use up and down to balance the load on the grid. "Historically, it's always been a responsibility of the grid and the generators to take care of energy loads," he says. "Now, we're developing paradigms where every load, every LED light—and everybody—can play a small part. But it can have a huge impact."

BOVINE INTERVENTION

From milk to cheese to manure, engineering innovations can keep farmers on the cutting edge

By Jason Daley

When people think of Wisconsin, they often imagine the iconic black and white Holstein cow. They're not wrong. About 1.2 million milk cows call the Dairy State home as well as hundreds of cheesemakers and dairy processors making yogurt, cream cheese and other products.

UW-Madison is no stranger to cows, either; it has one of the world's best dairy sciences programs, a dairy innovation hub, makes its own ice cream and even has a barn full of cows in the center of campus.

That focus on bovines has even made it into the College of Engineering, which is doing its part to make the dairy business more profitable, sustainable and better for cows (and their owners).

Stay cool, Bessie

One big issue facing dairy farmers is heat. Cows have a naturally high body temperature, meaning they don't tolerate above-average temperatures very well. And hot cows are less fertile and produce less milk, leading to billions of dollars in lost milk production per year. As climate change progresses, that's expected to get worse.

That's why Electrical and Computer Engineering Assistant Professor Younghyun Kim is leading an interdisciplinary team that's developing a cyber-physical system to mitigate heat stress on dairy cows. "Advances in machine learning and the Internet of Things have made it possible to understand and manage not only the digital world but also living animals," Kim says. "We want to answer the question of how we can promote productivity, sustainability and animal welfare in dairy farms using technologies."

Kim's solution, developed in cooperation with researchers from the College of Agricultural and Life Sciences and the School of Veterinary Medicine, is a system of both external sensors and those implanted in the cows that can continuously monitor their microenvironment and physiological stress. The data will allow farmers to monitor their cows' heat-stress in real time, while their barns will automatically adjust their cooling systems using just the right amount of energy and water.

A better whey

Whey, the watery byproduct produced in the cheese- and yogurt-making process, is often converted into whey powder, a high-protein supplement used by fitness buffs or added to some food and beverages. Whey from Greek yogurt is a bit more acidic and contains much less protein—so producers end up flushing 2 million gallons of the stuff annually.

But a handful of chemical and biological engineering graduate students aim to rescue that whey. Along with their chemical and biological engineering faculty mentors, Professor Emeritus James Dumesic and Richard L. Antoine Professor George Huber, they've taken the lead on finding a new use for the waste product. For several years, Mark Lindsay (PhDChE '21) led the charge with input from Food Science Professor Scott Rankin; now, research assistant Jarryd Featherman is at the helm.

Though it's low in protein, acid whey contains a lot of lactose and lactic acid, neither of which are particularly in demand. However, lactose can be broken into two high-value sugars, glucose and galactose. Using a solid-acid catalyst, the researchers found they could transform the lactose into a glucose-galactose syrup; in fact, Lindsay could use this syrup to make soft-serve ice cream.

By optimizing the system, the team now believes Greek yogurt manufacturers could produce this syrup in house and use it to sweeten their products—thus reducing whey waste, manufacturing costs and greenhouse gas emissions in the dairy industry.

Keep it on the farm

Besides producing milk, cows also produce a lot of manure—about 26.5 million tons per year. Farmers spread much of that manure on fields as fertilizer; however, manure contains excessive amounts of phosphorus, which builds up in soil and eventually washes into lakes and streams. Once in the water, the phosphorus feeds cyanobacteria, also known as blue-green algae, leading to an overgrowth that can suck up all the oxygen, kill aquatic creatures and foul beaches.

That's why Victor Zavala, Baldovin-DaPra Professor in chemical and biological engineering, and Brian Pfleger, Jay and Cynthia Ihlenfeld Professor in chemical and biological engineering, are collaborating with colleagues from the College of Agricultural and Life Sciences on an effort to tackle the negative impacts of manure.

Their idea is to transform manure into a more balanced fertilizer that won't contribute excess phosphorus to the soil. To do that, they are engineering specially tuned cyanobacteria that will process the manure in a bioreactor on the farm or at a local co-op. "We propose growing algae on the farms as opposed to letting it grow wild in the lakes," says Zavala. "The idea is to build bioreactors that use the manure as a medium for algae growth. Then you'll collect the algae and sell it as a biofertilizer."

Over time, the team hopes these fertilizers will help reduce the phosphorus built up in the soil, and as a result, also improve the quality of water in streams, rivers and lakes.

ETHICS

Some of the most heated discussions about technology don't have anything to do with operating systems or RPMs.

Rather, as new technologies change almost every facet of modern life, the big questions center around ethics, addressing topics that include privacy, the social responsibility of media platforms, the role of algorithms in perpetuating bias, and the sustainability of the energy we use or the products we buy.

One of the biggest considerations is the role of engineers in thinking about the downstream effects of their work. That's one reason our college charges its students, staff and faculty with keeping ethics at the center of their research and activities. The college aims to make sure students understand and follow ethical guidelines, and have the tools to assess and make ethical choices as they head into the workforce.

The college integrates ethics education into undergraduate education as a matter of course; ethics education is a requirement for college certification and is something the college takes seriously. "Ethics is inherent to our profession," says Ian Robertson, Grainger Dean of the College of Engineering, who considers ethics education one of the college's top priorities. "It's incumbent upon us to actually teach students about what it means to be an ethical engineer and how to put ethics in engineering into practice. So we've integrated ethics throughout the undergraduate curriculum and have serious discussions about issues like working with diverse sets of people, the social implications of engineering and ethics in business."

When it comes to research, the college also emphasizes ethical practices, like giving appropriate credit when it is due, dealing with power dynamics in research groups, and thinking about the broader impacts of research, like its effects on privacy or bias.

The college is advancing its commitment to leadership in ethics as well. Undergraduates participating in our National Academy of Engineering Grand Challenges Scholars Program must achieve competency in five areas, including multicultural competency and social consciousness. Students undertake practical projects to help them develop and apply these competencies during their engineering education and in their future endeavors.

Grand Challenges Scholars have pursued projects like analyzing ways to bring clean water to rural areas of Rwanda and the Dominican Republic and using machine learning to improve preventative health screenings. The goal is that these types of exercises will help engineering students understand the social ramifications of their work.

Electrical and computer engineering alumnus David Epstein (BS '76, MS '78), is also helping the college to refine its focus on ethics. Epstein is a longtime Silicon Valley engineer, tech investor, executive and business educator who is now the executive director of the Susilo Institute for Ethics in the Global Economy at Boston University's Questrom School of Business.

He says that when he first began guest lecturing at business schools and reflecting on his experiences in industry about 20 years ago, he realized he had encountered many ethical gray areas or breaches without recognizing them at the time. When the Volkswagen emissions scandal—in which regulators discovered the car company had rigged its vehicles to hide their true emissions—began in 2015, Epstein felt that engineers involved in that scandal should have felt empowered to push back.

Our focus on ethics makes us stand out

by Jason Daley

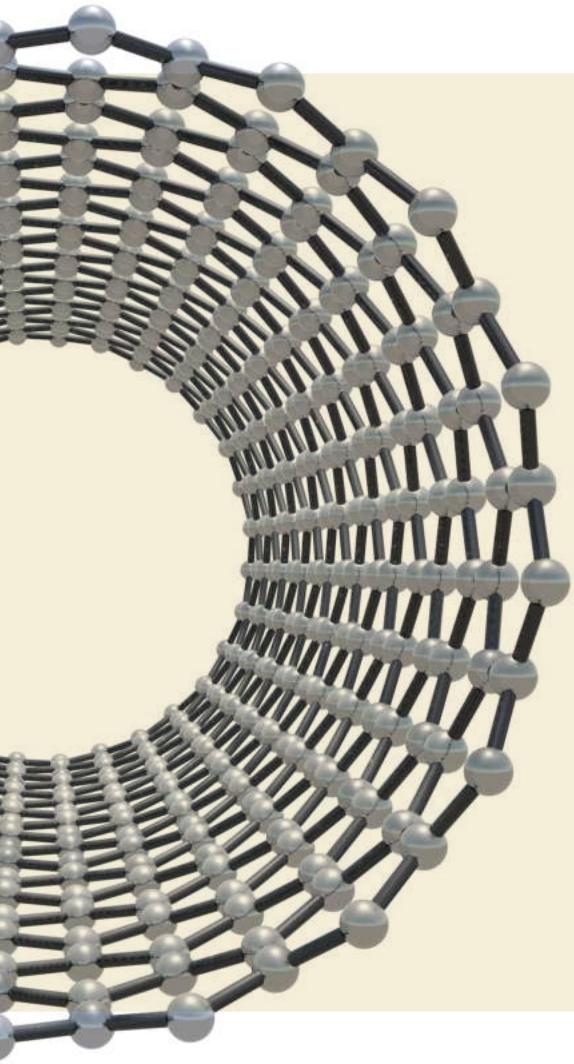
"In the face of something like that, an engineer should be thinking at a higher level," he says. "Engineers are always taught to solve problems and are given constraints. I want engineers to think about every constraint—not just a temperature range or how much power you have to use, but social, ethical and environmental considerations as well."

To that end, Epstein and his wife, Sarah, have funded a fellowship in ethics to support engineering graduate students to develop teaching modules about engineering ethics. They have also funded the Ethics in Engineering Distinguished Seminar in the college. In April 2021, the seminar hosted Tyler Shultz, who worked as an engineer at the biomedical firm Theranos, which promised to create a small machine that could perform hundreds of medical tests in just minutes. When Shultz began to voice doubts about the machine and detected instances of outright fraud, he was fired and attacked by his former employer.

Despite mounting personal and professional hardships due to his whistleblowing, Shultz persisted, dragging the Theranos fraud into the light. (Holmes has been found guilty on four charges of fraud).

Epstein says he hopes UW-Madison engineers would have the same grit in calling out an ethical breach. "I want engineers to leave Wisconsin not only with a sense of doing good, being socially aware and environmentally conscious," he says, "but also, as they create solutions, to believe that's a part of who they are."

Robertson agrees, and hopes to increase ethics awareness at all levels. "What these initiatives are doing is elevating the discussions about engineering ethics across the entire spectrum of undergraduates, graduates, faculty and staff," he says. "We want to get even better at ethics education; it's a continual evolution."



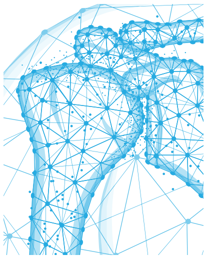
For computer chips, new technique puts carbon nanotubes squarely in their place

Every year or two for the past half century, researchers have found techniques for shrinking silicon transistors, roughly doubling the number that can be crammed onto a computer chip. That's enabled us to transition from room-sized computers to technologies like smartwatches in the span of a lifetime.

Now, however, silicon transistors are about as small as they can be, and researchers are investigating new, more efficient materials to replace silicon. One leading candidate is carbon nanotubes, which are tiny rolled-up pieces of the 2D wonder material graphene. As transistors, carbon nanotubes could be five times as energy efficient and five times faster than silicon—but the challenge is lining them up in the right way.

The secret is turning the nanotubes into 2D liquid crystals, according to research conducted by Materials Science and Engineering Professor Michael Arnold and recent graduate Katherine Jinkins (PhDMS&E '20). "In as little as 40 seconds, we can coat an entire 4-inch wafer with a uniform array of highly aligned carbon nanotubes," says Jinkins. "That fills a void that has existed in the carbon nanotube community for almost 30 years."

Needless to say, the process, which the researchers have patented through the Wisconsin Alumni Research Foundation, is a big advance for carbon nanotube research.



Device heals bones fast, then disappears without a trace

When you're trapped in a cast or navigating crutches, waiting patiently for a broken bone to heal can seem as agonizing as the injury itself.

Materials Science and Engineering Professor Xudong Wang feels your pain. His solution—the fracture electrostimulation device—could cut the wait and knit bones faster. It leverages the piezoelectric properties of bone, which produces a tiny bit of electricity when it's under strain. That electricity stimulates factors that promote bone growth and healing. Wang's device is thin, flexible, self-powered and implantable—and once the bone heals, its components also dissolve and disappear.

New condenser makes water from air, even in the hot sun

Using a revolutionary radiative vapor condenser, people worldwide could capture clean water 24 hours a day.

Existing systems collect "dew" produced overnight. However, the new design works in sunlight and requires no energy. Its vapor condenser is a thin film of polydimethylsiloxane, which releases heat in the mid-infrared range, layered over silver, which reflects sunlight. Combined, they cool the condenser below the dew point, leading to condensation.

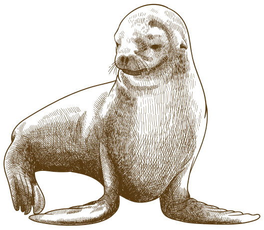
Its inventors, Electrical and Computer Engineering Associate Professors Zongfu Yu and Mikhail Kats and their collaborators, have formed a company to commercialize it. The next step? "Get water from the air for free using no energy," says Yu.

Connecting cartilage to a personal osteoarthritis treatment plan

Doctors can't see it, but those of us who have it sure can feel it: Osteoarthritis occurs when cartilage, the tissue that provides cushioning between our bones, wears away, causing pain and stiffness in that joint.

Hope for relief could be on the horizon, says Mechanical Engineering Assistant Professor Corrine Henak. "We'd like to be able to have a patient who is experiencing joint issues go in for a magnetic resonance (MR) scan. Then we'd develop a patient-specific computational model with cartilage material properties accurate to that patient's joint," she says. "This model could enable clinicians to better predict the likelihood of damage progression in the joint, and potentially help inform decisions about surgical procedures for patients."

Henak and her collaborators already have made an important step toward realizing this goal. Using an MR sequence—a specific series of pulsed radio waves—they've identified a significant correlation between one MR parameter and the cartilage's elastic behavior and its energy dissipation. Down the road, clinicians could use the MR sequence to noninvasively predict how your cartilage will fare.

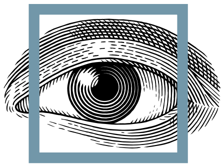


How seal whiskers can inform engineering designs

When a seal is looking for lunch, it relies on its unique whiskers, which have wavy surfaces that help the seal detect its underwater prey.

Those surfaces, which have an undulated cylinder geometry, also are useful to researchers. "Research has shown that this geometry significantly reduces forces and vibrations that result from interactions with fluids, making it attractive for many potential engineering applications," says Engineering Physics Assistant Professor Jennifer Franck.

Her own research could apply in areas ranging from underwater vehicles to wind turbine towers to forests.



Innovative patch is the next step in returning sight to injured retinas

Millions of people lose their vision due to macular degeneration or accidents that permanently damage the light-sensitive photoreceptors within their retina. UW-Madison researchers have generated new photoreceptors from human pluripotent stem cells. Now, an ophthalmologist, biomedical engineer and electrical engineer aim to implant those photoreceptors so that they can form appropriate connections. Their vehicle? A micro-molded ice-cube-tray-shaped patch that can hold more than 300,000 organized photoreceptors in an area approximately the size of the center of the retina. It's almost ready for testing in large animals.

FROM THE LAB

COLLEGE OF ENGINEERING RESEARCH NEWS

Increasing the potential for perfect metal parts

Electron beam powder bed fusion technology could enable manufacturers to make complex metal parts—everything from jet engine turbine blades to personalized biomedical implants and prosthetics. 3D printing those parts involves using an electron beam to melt and fuse layers of powdered metal under a vacuum.

Through his research, Charles Ringrose Assistant Professor in mechanical engineering Lianyi Chen aims to improve the printing process to mitigate defects in the resulting parts—enhancing manufacturers' ability to use the technology to make innovative complex products at high volume.

Several young faculty earn early-career honors

In 2021, seven of our assistant professors received the National Science Foundation's most prestigious early-career honor to support their research, bringing our total number of recipients in the last three years to 19. Recipients include Biomedical Engineering Associate Professor Megan McClean, Chemical and Biological Engineering Conway Assistant Professor Reid Van Lehn, Civil and Environmental Engineering Charles G. Salmon Assistant Professor Pavana Prabhakar and Assistant Professor Hiroki Sone, Electrical and Computer Engineering Assistant Professors Line Roald and Joshua San Miguel, and Mechanical Engineering Assistant Professor Dakotah Thompson.

Make up your mammogram (or other diagnostic test)

During the pandemic, hospitals, clinics and patients have postponed elective procedures and routine appointments—but that can mean diseases go undetected and untreated. In an analysis applicable to many diseases and future scenarios, Oguzhan Alagoz, the Proctor and Gamble-Bascom Professor in industrial and systems engineering, led a study of the long-term impact of delayed preventative care on long-term breast cancer mortality. His team's models showed a half-percent increase in deaths over non-pandemic projections, driven primarily by reductions in mammography screenings and diagnostic visits.

While that outcome was better than expected, Alagoz notes that any additional deaths are still premature losses of life—and that patients who missed a mammogram should make it up rather than wait until their next regularly scheduled screening.

New faculty add exciting expertise to a growing college

This year, we welcomed eight professors with impressive academic credentials from institutions such as the Massachusetts Institute of Technology, Imperial College London, the University of California, Santa Barbara, and the University of California, Berkeley. They're excited about the opportunity to work and collaborate at UW-Madison.

Styliani Avraamidou, an assistant professor of chemical and biological engineering who's studying ways to transition traditional supply chains into more sustainable circular economy systems.

Chirag Gupta, an assistant professor of electrical and computer engineering who's bringing tech industry experience to the next-gen semiconducting materials he studies and fabricates.

Katherine (Kate) Fu, an associate professor of mechanical engineering who's using cognitive science tools and data to improve engineering design and innovation.

Siddarth Krishna, an assistant professor of chemical and biological engineering who's designing catalysts for sustainable chemistry applications.

Shubhra Pasayat, an assistant professor of electrical and computer engineering who's designing and fabricating energy-efficient semiconductors from gallium nitride and related materials.

Michael Wehner, an assistant professor of mechanical engineering who's studying how robots interact with their environment, including ways that robots could safely interact with people.

Qiaomin Xie, an assistant professor of industrial and systems engineering who's building the theoretical foundation for data-driven decision-making.

Jun Xiao, an assistant professor of materials science and engineering who's advancing understanding of quantum materials for information and energy applications.

Following herbicides into —and ideally out of— Wisconsin's lakes

The invasive aquatic plant Eurasian watermilfoil grows in thick blankets just under the surface of a body of water, effectively blocking sunlight from reaching other beneficial plant species nearby.

While environmental managers try to control the invasive with herbicides such as 2,4-D, triclopyr, fluridone and others, solving one problem may introduce another.

That's why environmental chemistry and technology PhD student Amber White is studying how those herbicides might also linger in the environment. Focusing on 2,4-Dichlorophenoxyacetic acid, or 2,4-D, and florpyrauxifen-benzyl, White combined work in the lab with extensive sampling in several Wisconsin lakes.

To study the herbicides' breakdown process, she took water and sediment samples from the lakes before they were treated with the chemicals. Back in the lab, she set up microcosms to test the water and soil, then added the herbicide. "In some of our lab tests, we try to isolate the bacterial community to see how quickly it breaks down the chemicals," White says. "That removes the effects of things like sunlight or runoff. In other tests, we're looking at photochemical degradation, to see how quickly sunlight alone breaks down the herbicide. We can take that and compare it to additional samples we take after the actual lakes have been treated to see what's driving those processes."

After the lakes were treated, White aggressively sampled the sediment and water in the first 72 hours after application, then slowed to weekly sampling. After a few weeks, she shifted to monthly samplings to continue to observe how the chemical degrades in the water.

She found strong evidence that bacteria break down 2,4-D in the environment. In the lab, she says, the photolytic degradation of 2,4-D was very slow, and the chemical took hundreds of days to reach its half life. Conversely, in the lake, 2,4-D had a half life of six to 24 days—a fast speed that aligned with what she observed in the bacterial microcosms. "We really believe microbes in the sediment are driving the degradation," she says. "There's a lot of previous literature that suggests bacteria can use 2,4-D as a food source. Really, they're just eating it, like they would eat anything else."

While none of the observed lakes are used for drinking water, they are used recreationally. "We were seeing that 2,4-D was gone from the lakes usually within a month of treatment," says White.

Though she's not finished studying florpyrauxifen-benzyl, White says the substance already seems to be "stickier" than 2,4-D—meaning it may be more likely to cling to the soil or suspended carbon-based solids in the water.

White studies under Civil and Environmental Engineering Associate Professor Christy Remucal and Vilas Distinguished Achievement Professor Trina McMahon. For the project, she also has worked with three undergraduate civil and environmental engineering students and a master's student who's studying bacteriology. It's a great example of the types of collaboration common in UW-Madison's research. "Not only is this research cool, but I'm especially proud that we've been able to have so many undergraduates involved and getting hands-on experience, and to bring in another student from a different area of study," she says.

For real

civil engineering students learn in a virtual world

In Hannah Blum's Steel Structures 1 class, there's more than meets the eye.

Blum, an assistant professor of civil and environmental engineering and the Alain H. Peyrot Fellow of Structural Engineering, is using a blend of augmented and virtual reality learning tools to help students visualize—in striking detail—the sorts of work they'll do as structural engineers.

For one such learning tool, Blum is using Microsoft HoloLens. The HoloLens fits like a pair of futuristic glasses and projects a computer-rendered image over the wearer's field of vision. In one class period, for example, Blum's students used the technology to view a bolted steel connection. Using the HoloLens controller, they could interact with the steel as if it were in front of them, and pull it apart to see what an actual fracture would look like. The accompanying software application asked students to identify which pieces of the steel structure would break off together and provided immediate feedback on their answers.

"If you compare this to what's in textbooks, students are getting much better visualization through the HoloLens," Blum says. "It's there in 3D; you can walk around and view it from different angles. You can virtually hold it, twist it, pull it apart and put it back together. This is so much better compared to looking at a book."

In the Kohler Innovation Visualization Studio in the college's makerspace, her students have used Oculus virtual reality headsets—for example, to take a guided tour of the 51st floor of a Chicago skyscraper under construction. The tour's narrator, who was the project's lead engineer, explained engineering concepts as students moved throughout the construction site, also interacting with various popups along the way for even more information. "This was the type of tour they'd get if they were on a class field trip," Blum says. "You stop at a point of interest and a guide would talk, point things out, and then you'd move to the next stop. This is a great tool for us because field trips like this aren't often an option."

To create this unique experience for her students, Blum and her PhD student Ed Sippel worked with partners on campus and in industry. Blum and Sippel designed the tools with aid from the UW-Madison Division of Information Technology's web and mobile solutions team as well as the Wisconsin Institute for Discovery, and a computer science undergraduate student programmed much of the HoloLens tool. The American Institute of Steel Construction was a major partner for the virtual construction tour and provided a model for another virtual reality tool in which students matched floor plans to a virtual three-story building. Blum also has received grants from the College of Engineering and from the UW-Madison provost's office to support her work so far.

It sounds like a big undertaking, but she says it's worth the effort; it's important not only as a fun, hands-on way for students to learn but also because it gives students an idea of what to expect in their careers. "Companies are starting to use this technology," she says. "They might have a virtual reality walkthrough for a client to show what a building looks like. Some construction software companies are using mixed reality to overlay models onto construction sites. We want students to be familiar with this technology so that they're prepared when they go out into the workforce."

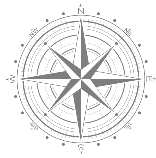
New major is a natural fit for undergrads

In 1970, the Department of Civil Engineering changed its name to the Department of Civil and Environmental Engineering—adding two words that to this day reflect the important, complementary and yet distinct role environmental engineering plays within the discipline.

Fifty-one years later, the department has established the first formal bachelor's degree in environmental engineering—a field that has been an option for years for undergraduates majoring in civil engineering. "We've had quite a few students who have wanted to focus solely on environmental engineering as well as employers seeking graduates with such a focus," says Civil and Environmental Engineering Professor Greg Harrington, who led the major's creation. "We've also had quite a few inquiries from prospective students about it while they're considering us against other institutions. This now allows our students to focus on the disciplines within environmental engineering and get more depth in the field that they couldn't get otherwise."

Advisory capacity

In class, grad students learn the science of mentoring



In academia, a good mentor can help guide the course of a young student's career, open doors to new opportunities, and accelerate growth and learning.

Offered in fall, winter and summer, a research mentor training practicum for chemical engineering grad students helps them learn mentoring skills and create a more meaningful experience for the undergrad researchers who often work alongside them in the lab.

It centers around group discussion, following a curriculum based on *Entering Mentoring*, a widely used text on mentoring in STEM fields developed at UW-Madison. Students also work through case studies in the book and discuss real-life scenarios happening in their own labs.

While training grad students to become better mentors benefits the undergraduates they supervise, the course also enables grad students to develop more positive relationships with their own advisors and other researchers.

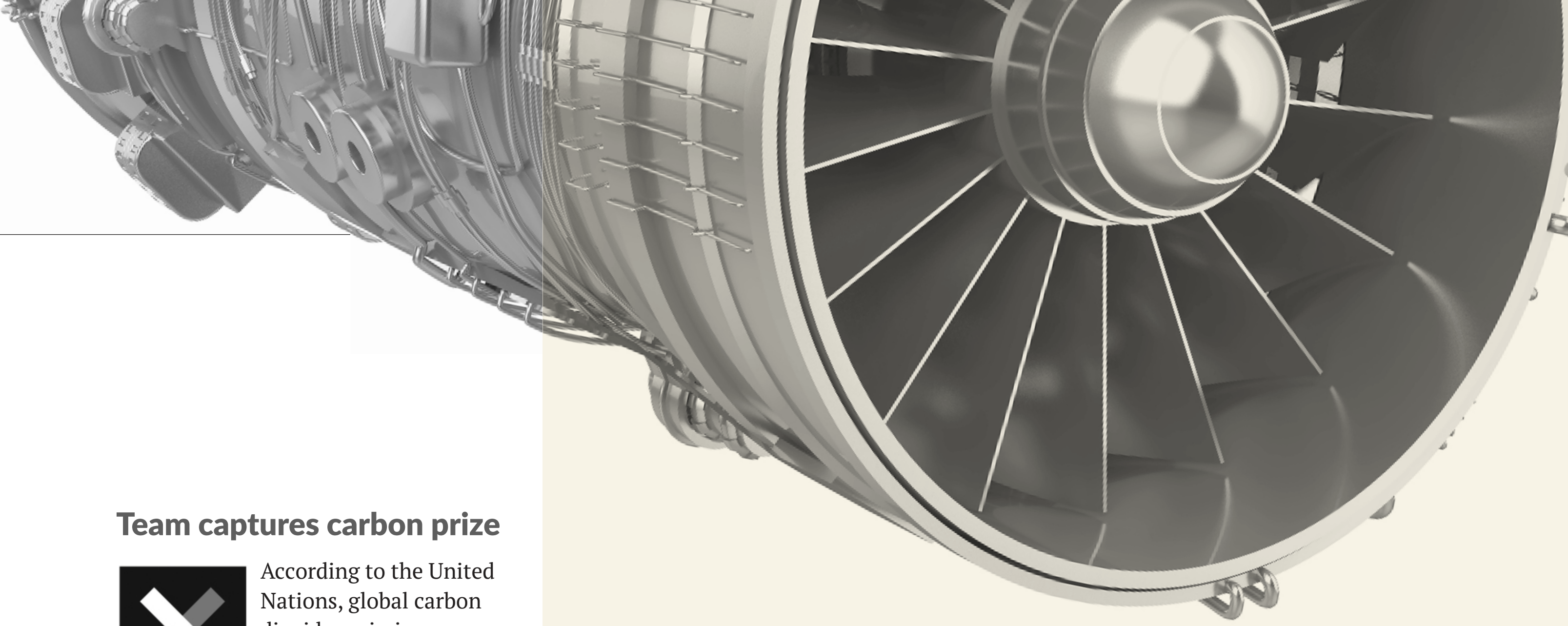
What do you do with data?

New intro analytics course teaches engineering students statistical fundamentals

A new engineering course, *Intro to Industrial Statistics*, gives undergrads an intro to analytics they can use in their career.

In the course, students learn the basics of probability, a range of data tools in Microsoft Excel, and statistical techniques like linear and multiple regression. By the end of the semester, they'll have tackled a case study covering statistical quality control, a classic industrial engineering assignment. And throughout the semester, they work on team projects, applying methods learned in class to datasets of their choosing culled from the public data science repository kaggle.com. (Project topics in fall 2021 ranged from pinpointing the population characteristics that best indicate whether a tumor is likely to be malignant in breast cancer diagnoses to applying regression methods to study the physical characteristics of opossum populations.)

"We wanted to create a course that would give that fundamental training in a practical, hands-on way that would be meaningful and relevant to engineering students," says instructor Amanda Smith. "Instead of just formulas and theory, we focus on topics like, 'Here's how we use statistics. Here's the practical, day-to-day reality of working with data. It's messy; you don't always know if it's what you really need. Here's how you begin to understand what your data is telling you and how you can use it well.'"



Team captures carbon prize

According to the United Nations, global carbon dioxide emissions reached a massive 59 billion tons—in 2019 alone. With $250,000 from the XPRIZE for Carbon Removal Student Competition, a transdisciplinary team of our students aims to take a big chunk of that CO_2 out of the air and seal it away where it can't contribute to rising global temperatures.

Consisting of graduate and undergraduate students from the College of Engineering, the College of Agricultural and Life Sciences, the College of Letters and Science, and the Nelson Institute for Environmental Studies, the team was among recipients of the largest award available in the $5 million competition. Sponsored by the Musk Foundation, it is kickstarting projects that could mitigate the impacts of climate change by removing carbon dioxide from the air, ground and oceans.

With guidance from Civil and Environmental Engineering Assistant Professor Bu Wang and Biological Systems Engineering Professor Rob Anex, the team is developing a two-part system that consists of a direct air capture unit that traps carbon dioxide from the air, plus a carbonization component that converts the captured CO_2 into limestone particles.

As the team moves forward in the XPRIZE contest, which runs through Earth Day 2025, members will further refine the system, figure out how to scale it up, and develop a plan for its implementation. "The goal is to commercialize the process," says team leader Keerthana Sreenivasan, a graduate student in civil and environmental engineering. "We're trying to get it to a startup."

Aerospace option launches careers

The aerospace industry offers many career opportunities for engineers, who can apply their skills to challenges involving rockets, spacecraft, airplanes and more—and our engineering mechanics and astronautics graduates have gone on to work at NASA, Lockheed Martin, Boeing, United Launch Alliance, GE Aviation, the NASA Jet Propulsion Laboratory, Joby Aviation, and ATA Engineering, among others. EMA graduates also found their own companies—for example, Dark Aero, an innovative company intent on disrupting the kit aircraft industry.

Photo: Dark Aero

Now, however, engineering mechanics undergrads can add a more recognizable credential to their degree: In fall 2020, the Department of Engineering Physics changed the name of its longstanding "astronautics" option to the aerospace option. "The aerospace label will make it easier for our students to connect with companies at career fairs and elsewhere," says Paul Wilson, Grainger Professor of Nuclear Engineering and the department's chair.

And because the aerospace option is based in the department's highly regarded engineering mechanics degree program, students also receive a well-rounded education and develop versatile skills, making them even more able to perform at a high level in the workplace.

Certificate equips undergrads to lead effectively

Undergrads in the college's Emerging Leaders Program embark on a journey that includes introspection, strengths coaching, a one-on-one mentoring relationship with an engineering alum, a small-group community-based project, and developing a change initiative around an issue important to them. To earn an engineering leadership certificate, all participants in the program also must be involved in a student organization and complete the course, InterEGR 303: *Applied Leadership Competencies in Engineering*.

One goal of the ELP is to marry the "soft" and technical skills students need to be successful engineers. "I found discussions to be insightful as we talked about topics such as psychological safety, which are not normally discussed in other engineering classes," says industrial engineering student Sydney Tong. "I also found the strengths module to be very beneficial as it was a great way to learn about my strengths and how I can leverage them in both my professional and personal life."

HONORING ELITE ALUMNI

Filtering particles, from pollution to pandemic

While studying abroad in Singapore as mechanical engineering undergrad in 2013, Max Bock-Aronson learned what it's like to live with a lot of air pollution.

Ironically, he also was taking an engineering course on air pollution. He also learned that the masks people commonly wore in Southeast Asia, such as cloth masks and surgical masks, filter fewer particles—in contrast with N95 masks, which are highly effective at filtration, but less comfortable for daily wear. "I wanted something that looked like a cotton mask and was a better fit for my lifestyle but that offered the protection of the N95 masks," he says.

That idea was the genesis for what would eventually become the B2 Mask, an innovative, reusable face mask developed by Breathe99, the Minneapolis-based startup company Bock-Aronson co-founded.

TIME magazine selected the B2 Mask as one of the best inventions of 2020, a year when the global COVID-19 pandemic thrust face masks into the spotlight as consumer products.

Bock-Aronson says his UW-Madison engineering education, and the opportunities he capitalized on as a student, played a crucial role developing his entrepreneurial skills.

Back then, he even designed a rough prototype of a mask and entered it in the College of Engineering's 2014 Innovation Days competition (he won second place and earned some prize money).

After graduating with his bachelor's degree in mechanical engineering, Bock-Aronson worked as a mechanical design engineer at product design consulting firms. In his spare time, he continued to tinker with his mask design and founded Breathe99 with friends Coleman Rollins and Joel Valdez.

In March 2019, he moved to part time in his job to focus on bringing the mask to market. A year later, he watched as a novel coronavirus started spreading rapidly around the world, then transitioned to full time at Breathe99. "It was becoming more and more obvious that COVID-19 was going to be a big problem," he says. "And I had designed a mask that, although it was initially focused on air pollution, I thought could be helpful in fighting against the coronavirus."

Breathe99 launched a Kickstarter crowdfunding campaign in April 2020 and the project quickly surpassed its goal, generating $500,000 in pre-orders in 20 days. "We moved very quickly from a high-fidelity prototype in April to starting the first deliveries of a manufactured product to customers in June 2020," Bock-Aronson says.

The B2 mask has a flexible, rubber-like face piece that creates an airtight seal on the wearer's face. The face piece holds two replaceable filters, and both it and its fabric overlay are machine washable. "The B2 Mask offers a very high filtration efficiency comparable to an N95 mask, but the B2 Mask is reusable and more comfortable for many people than N95 masks," Bock-Aronson says.

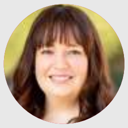
He says it's an amazing feeling to be included in *TIME* magazine's list of the best inventions of 2020. "It's particularly meaningful because our product is bringing peace of mind to people during this difficult time and that's the whole reason we started the company in the first place," he says.

Alumni eye

Meet nine grads who are making a unique mark on the world

We often tell our students that, while a UW-Madison engineering education prepares them well to be engineers, it also means the possibilities—and opportunities—are endless. Our alumni bear that out. And for every example we see of your leadership within the engineering field, we also encounter alumni whose education was a springboard into something else entirely. Here, we're introducing a blend of both—the outstanding alumni who received early-career or distinguished achievement awards from the college in 2021.

Early-Career Award Recipients



Kara Byrne
(BSME '04)

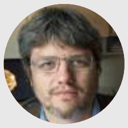
North America Commercial leader, turbomachinery and process solutions-valves, Baker Hughes

Kara is a technical and strategic leader in energy, valves and turbomachinery whose passion for inspiring women to enter engineering has enabled her to mentor, develop and retain future women leaders in the energy industry.

Daniel R. Grice
(BSMS&E '09)

Senior materials engineer, Materials Evaluation and Engineering, Inc.

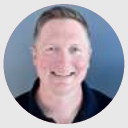
Dan is a materials engineer who has significantly advanced the diagnosis and remediation of material failures, provided exemplary professional society leadership, and promoted careers in STEM.



Paul Dauenhauer
(BSChE '04)

Lanny and Charlotte Schmidt Professor, chemical engineering and materials science, University of Minnesota

Paul is a chemical engineer whose ingenious catalytic processes have revolutionized biomass use and led to three startup companies that put his inventions into practice.



Benjamin W. Longmier
(BSEP/physics '04, MSEP '05, PhDEP '07)

CTO and co-founder, Swarm Technologies

Ben is a nuclear engineer whose expertise in aerospace engineering has enabled him to found three companies focused on high-altitude/low-earth-orbit communications to accelerate the Internet of Things.

Distinguished Achievement Award Recipients

Bjorn Krogh Borgen
(BSME '62)

Chairman, Borgen Investment Group

Bjorn is a leading financial manager and entrepreneur whose success has enabled him to support educational, athletic and cultural causes that have benefited people across the United States and in his home country of Norway.

David Ira Epstein
(BSECE '76, MSECE '78)

Executive director, Susilo Institute for Ethics in a Global Economy, Boston University; venture advisor, investor and management consultant, Epstein Advisors

David is an entrepreneur in cleantech, semiconductors and healthcare who has demonstrated an unwavering commitment to social responsibility and ethics.

Moo Hwan Kim
(PhDNE '86)

President, Pohang University of Science and Technology

Moo Hwan is a nuclear engineer and academic leader whose innovations significantly improve understanding of two-phase flow and heat transfer in nuclear energy systems.

Brian E. Luedtke
(BSChE '85)

Vice president, Asia Pacific region, global corporate communications and clinical education, Hollister Inc.

Brian has improved life for patients with chronic conditions by supporting innovative technology development, effective partnerships with healthcare providers, and sustained community engagement.

Stephanie M. Whitehorse
(BSMS&E '96)

Director of intellectual property, physical sciences, Wisconsin Alumni Research Foundation

Stephanie played a major role in evaluating, patenting and commercializing more than 1,500 UW-Madison inventions, which have generated more than $100 million of royalty income and formed the basis of 45 startup companies.

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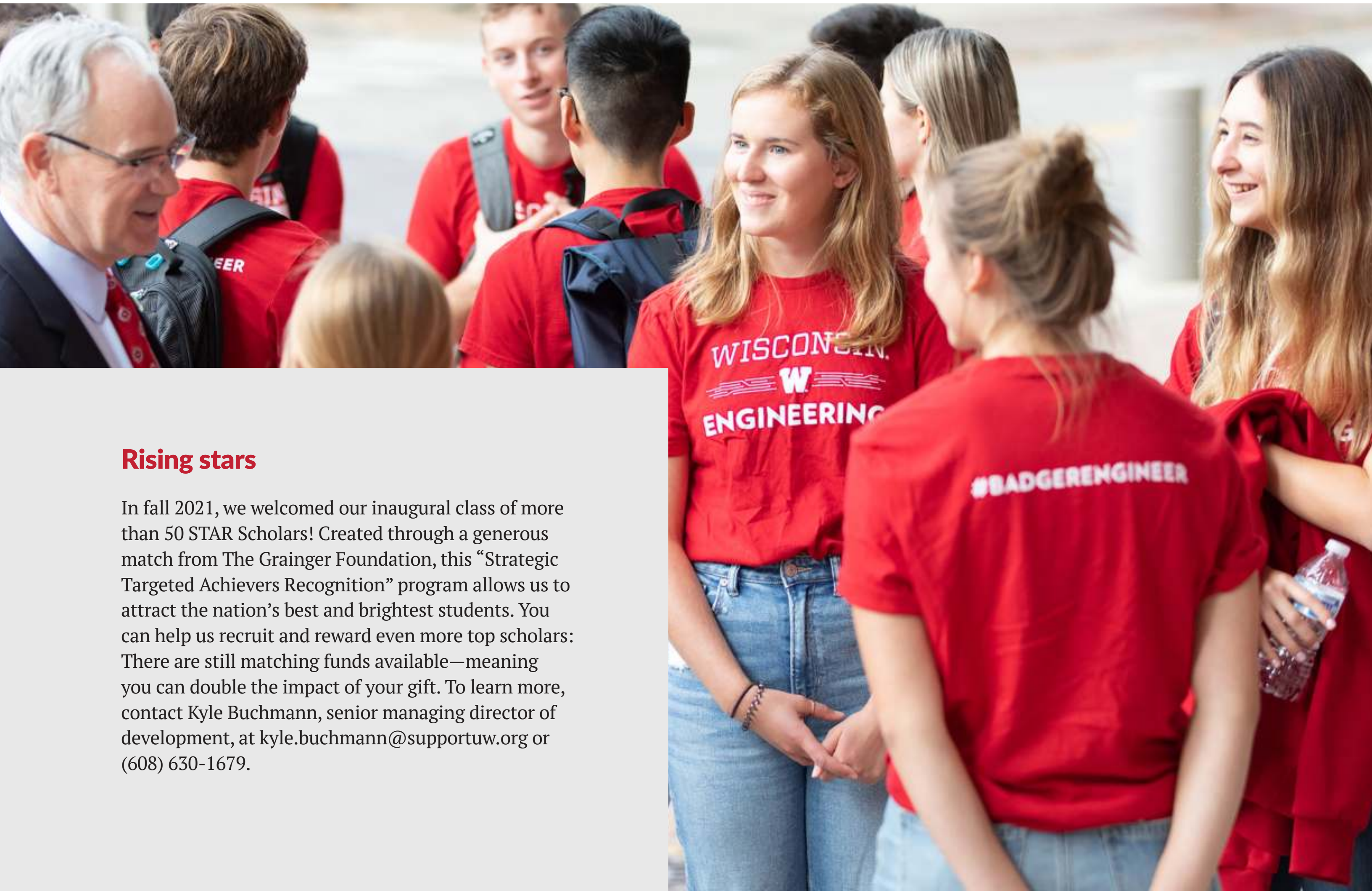

Rising stars

In fall 2021, we welcomed our inaugural class of more than 50 STAR Scholars! Created through a generous match from The Grainger Foundation, this “Strategic Targeted Achievers Recognition” program allows us to attract the nation’s best and brightest students. You can help us recruit and reward even more top scholars: There are still matching funds available—meaning you can double the impact of your gift. To learn more, contact Kyle Buchmann, senior managing director of development, at kyle.buchmann@supportuw.org or (608) 630-1679.