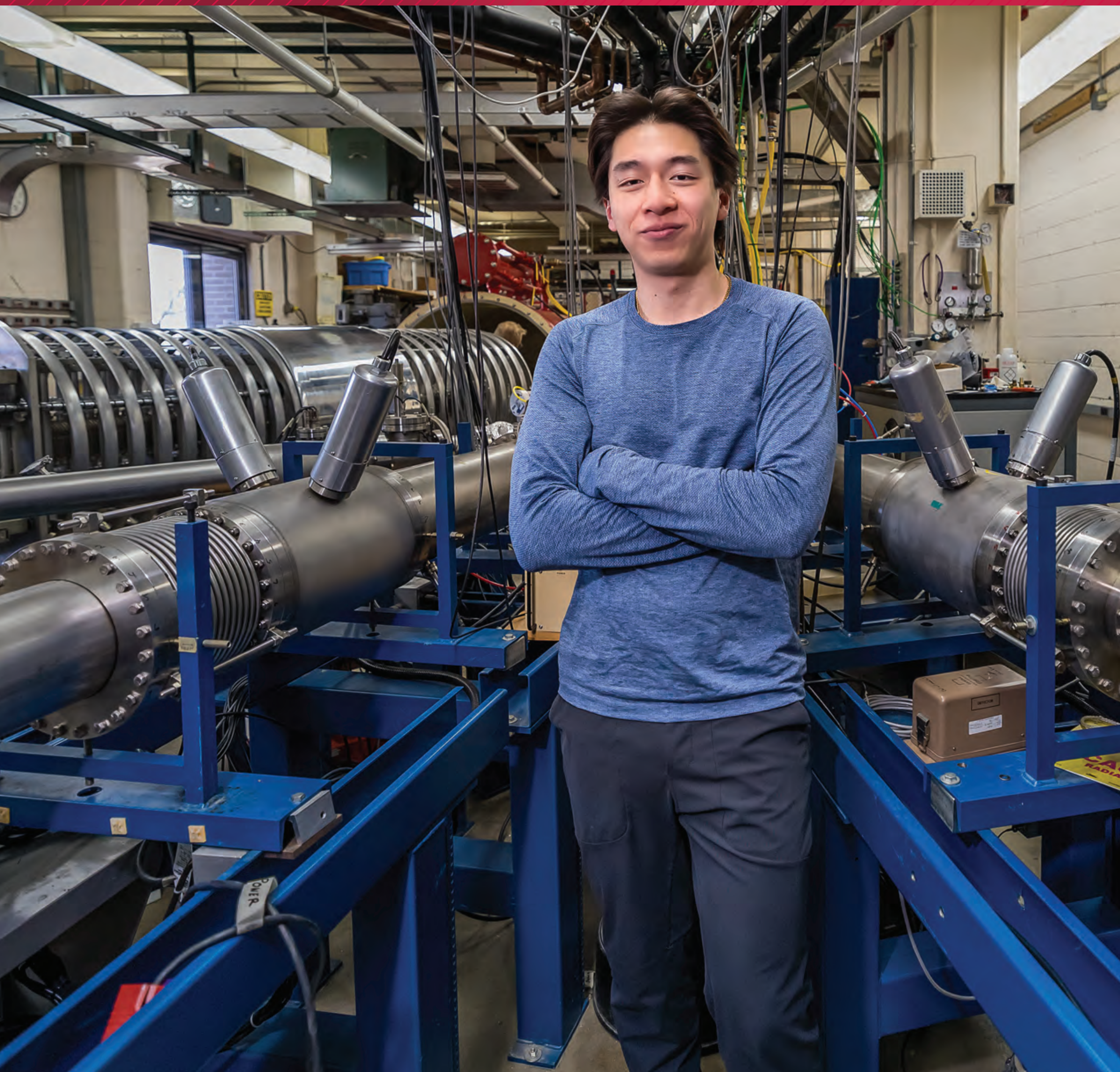
College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

SPRING 2024 NEWSLETTER

DEPARTMENT OF

NUCLEAR ENGINEERING AND ENGINEERING PHYSICS



Greetings from Madison!

Our nuclear engineering program is growing! We began this year with 30% growth in our undergraduate enrollment. There are probably a few drivers for this sudden change, and already some exciting consequences.

At the national level, the narrative for nuclear energy has changed. After a decade where the leading stories were about plant closures, a growing focus on the challenges of climate change have been reinforced by bipartisan federal policy to put nuclear energy in the spotlight as a critical part of our future energy system. Excitement over fusion energy adds to this story and brings local connections, with three companies generating interest in the Madison area. It probably didn't hurt to have Miss America on our side, either.

At the local level, the Department of Nuclear Engineering and Engineering Physics has worked hard to get the story out with a focus on first-year students who are already on campus. Drawn in by open houses that include tours of the UW Nuclear Reactor (UWNR) or the Pegasus-III and HSX fusion experiments, we get an opportunity to reinforce this national narrative while introducing students to the benefits of our close-knit community with ample research opportunities and a rich employment market experienced by our graduates.

At the center of this story is our first-year course that builds community and gives students a chance to build a project to be deployed at the UWNR, while exposing them to the richness of the field. This year's offering had a waiting list and included students from other engineering majors. Students in our sophomore and junior classes routinely bring up the value of this course as part of their introduction to the major and the nuclear engineering community.

One of my favorite outcomes of this new energy is the reemergence of our American Nuclear Society (ANS) student section. Half the executive board is composed of sophomores and first-year students who bring enthusiasm to the ideas of their upper-class peers and contribute new ideas of their own to expand the variety of activities. As ANS expands its outreach activities and explores new professional development opportunities in Madison and environs, it will be taking 32 students to participate in this year's ANS student conference.

We do anticipate some challenges: As the numbers grow, we'll need to offer more sections of our lab courses and ensure a rich set of electives to satisfy the diverse interests those students bring to the table. As a research leader in the College of Engineering, we'll be looking for innovative ways to expand our instructional offerings while maintaining research excellence and navigating anticipated faculty retirements. We also expect to have an even greater pool of excellent students to receive our scholarships; our hope is that we can offer scholarships to all those who deserve.

Hopefully, I'll be reporting back next year with another increase in enrollment and how we have begun to tackle the challenges that come with it.

On, Wisconsin!

Paul Wilson
Chair and Grainger Professor of Nuclear Engineering
(608) 263-0807
chair@neep.wisc.edu

On the cover: Undergraduate student Bao-Phong Nguyen, a Hilldale undergraduate research fellowship recipient, in the Ion Beam Laboratory, where he conducts research on materials degradation in extreme environments as a member of Associate Professor Adrien Couet's lab. Photo: Joel Hallberg.

Undergraduate Q&A: Virginia Lilly

Virginia Lilly is a junior from Westchester, New York, and the vice president of the Wisconsin Engineering Student Council, which collaborates with Engineering Student Development staff to plan events and support engineering related clubs on campus. She shares insights about her engineering education.

What drew you to nuclear engineering?
I considered joining the Navy when I was in high school and became interested in aircraft carriers because they can operate for long periods without refueling, thanks to nuclear power. I then applied to most of the colleges across the country with nuclear engineering programs and UW-Madison seemed like the best balance between a great education and student life.

What have been the highlights of your education?
Since the NEEP department is quite small, I know all the other students in my major and the faculty make an effort to know us, too. The first week of my freshman year, Paul Wilson, the chair of the NEEP department, reached out to the freshmen in the nuclear engineering major to set up a time to meet him and for us to meet each other. It meant a lot to me that at a school with nearly 40,000 undergraduate students, the chair of my department would take time out of his schedule to meet us.

What's been your favorite course? NE 305: *Introduction to Nuclear Engineering*. It's a great class that lays the foundation for future courses. We covered quantum mechanics, radioactive decay, fission and radiation detection. The instructor Laura Bartol is an excellent teacher and organized all of the content in easily digestible lectures.

What are your career plans? I'm interested in the economic side of engineering projects, especially since the main roadblock in most nuclear projects is cost. I'm currently researching methods to estimate advanced reactor cost, which I could see myself pursuing a career in.

engineering.wisc.edu/neep
go.wisc.edu/linkedin-neep
@uwmadisonneep
@uwmadisonneep

‘Wonder’ material gulps down hydrogen, spits it out, and protects fusion reactor walls

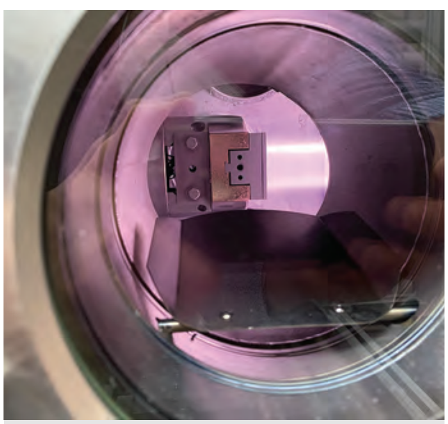
Graduate students Evan Willing (left) and Tyler Dabney set up equipment to apply a coating via cold spray in Professor Kumar Sridharan’s Cold Spray Laboratory. Photo: Joel Hallberg.

UW-Madison engineers have used cold spray coating technology to produce a revolutionary workhorse material that can withstand the harsh conditions in a fusion reactor.

The advance, detailed in a paper published in October 2023 in the journal *Physica Scripta*, could enable more efficient compact fusion reactors that are easier to repair and maintain.

“The fusion community is urgently looking for new manufacturing approaches to economically produce large plasma-facing components in fusion reactors,” says Mykola Ialovega, a NEEP postdoctoral researcher and lead author on the paper. “Our technology shows considerable improvements over current approaches. With this research, we are the first to demonstrate the benefits of using cold spray coating technology for fusion applications.”

The researchers used a cold spray process to deposit a coating of tantalum, a metal that can withstand high temperatures, on stainless steel. They tested their cold spray tantalum coating in the extreme conditions relevant to a fusion reactor and found that it performed very well. Importantly, they discovered the material is exceptionally good at trapping hydrogen particles, which is beneficial for compact fusion devices.



Postdoctoral researcher Mykola Ialovega performed plasma irradiation tests on the cold spray tantalum coating samples at Forschungszentrum Jülich GmbH in Germany. Pictured above, the researchers’ cold spray tantalum sample is being exposed to deuterium plasma. Photo courtesy of Mykola Ialovega.

“We discovered that the cold spray tantalum coating absorbs much more hydrogen than bulk tantalum because of the unique microstructure of the coating,” says Grainger Professor Kumar Sridharan, whose research group, over the last decade, has introduced cold spray technology to the nuclear energy community by implementing it for multiple applications related to fission reactors. “The simplicity of the cold spray process makes it very practical for applications.”

In fusion devices, plasma—an ionized hydrogen gas—is heated to extremely high temperatures and atomic nuclei in the plasma collide and fuse. That fusion process produces energy. However, some hydrogen ions may get neutralized and escape from the plasma.

“These hydrogen neutral particles cause power losses in the plasma, which makes it very challenging to sustain a hot plasma and have an effective small fusion reactor,” says Ialovega, who works in the research group of Thomas and Suzanne Werner Professor Oliver Schmitz.

That’s why the researchers set out to create a new surface for plasma-facing reactor walls that could trap hydrogen particles as they collide with the walls.

Tantalum is inherently good at absorbing hydrogen—and the researchers suspected that creating a tantalum coating using a cold spray process would boost its hydrogen-trapping abilities even more.

Creating a cold sprayed coating is somewhat like using a can of spray paint. It consists of propelling particles of the coating material at supersonic velocities onto a surface. Upon impact, the particles flatten like pancakes and coat the entire surface, while preserving nanoscale boundaries between the coating particles. The researchers discovered that those tiny boundaries facilitate trapping of hydrogen particles.

Experiments revealed that when the coated material was heated to a higher temperature, it expelled the trapped hydrogen particles without modifying the coatings—a process that essentially regenerates the material so it can be used again.

“Another big benefit of the cold spray method is that it allows us to repair reactor components on site by applying a new coating,” Ialovega says.

The researchers plan to use their new material in the Wisconsin HTS Axisymmetric Mirror (WHAM). The experimental device is under construction near Madison, Wisconsin, and will serve as a prototype for a future next-generation fusion power plant that UW-Madison spinoff Realta Fusion aims to develop. Housed in the Physical Sciences Laboratory, the WHAM experiment is a partnership among UW-Madison, Massachusetts Institute of Technology, and Commonwealth Fusion Systems.

The researchers are patenting their technology through the Wisconsin Alumni Research Foundation.

UW–Madison part of effort to advance fusion energy with machine learning

A new collaboration built on open-science principles is using machine learning to advance knowledge of promising sources of magnetic fusion energy.

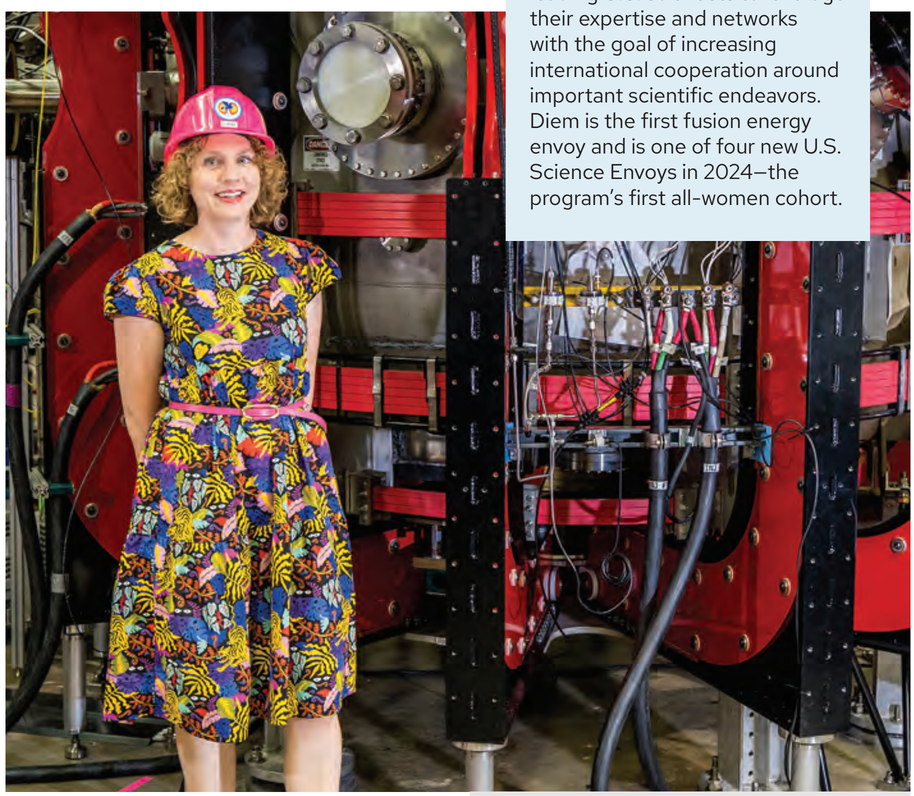
The teams—among them UW-Madison researchers—will create a platform to publicly share data they glean from several unique fusion devices and optimize that data for analysis using artificial intelligence tools. Student researchers from each institution will participate in a subsidized summer program to focus on applying data science and machine learning to fusion energy. The U.S. Department of Energy is funding collaboration, led by researchers at the Massachusetts Institute of Technology, with nearly $5 million over three years.

The data sources will include UW-Madison's Pegasus-III experiment, which is centered around a fusion device known as a spherical tokamak. A primary goal of the experiment is to study innovative ways to start up future fusion power plants. "I'm incredibly excited to be a part of projects like this one as we continue to push innovation both in the analysis and development of experimental devices and diverse workforce development initiatives," says Assistant Professor Steffi Diem, who leads the Pegasus-III experiment.

Diem is an emerging leader in the fusion research world. In 2022, she was invited to present at the White House's Bold Decadal Vision for Commercial Fusion Energy that launched several efforts focused on commercializing fusion energy. In a field traditionally dominated by men, Diem is also one of four women leading the new collaboration. "Throughout much of my career, I have often been one of the few women in the room, so it is great to be a part of a collaboration where four out of the five principal investigators are women," Diem says.

The collaboration is based around the principles of open science; Diem and her colleagues will make the wealth of data coming from Pegasus-III and other fusion experiments more accessible and usable to others, particularly for machine learning platforms.

While this approach is designed to accelerate knowledge of magnetic fusion devices, it's also aimed at providing a more accessible path into fusion research programs for students with wider skillsets and backgrounds, particularly in data sciences. Building a more diverse fusion workforce will be tantamount going forward, says Diem.



Assistant Professor Stephanie Diem studies innovative techniques for starting a plasma with the new Pegasus-III experiment. Photo: Joel Hallberg.

"Fusion isn't just plasma physicists anymore," she says. "As fusion moves out of the lab and toward the goal of providing clean energy to communities, it requires an interdisciplinary approach with engineers, data scientists, skilled technical staff, community members and more."

UW-Madison is supporting a broader push to diversify the fusion field. Some of the student researchers who will be participating in the new collaboration are part of the student-led Solis group, which provides gender-inclusive support for students studying plasma physics on campus.

Fusion Leader

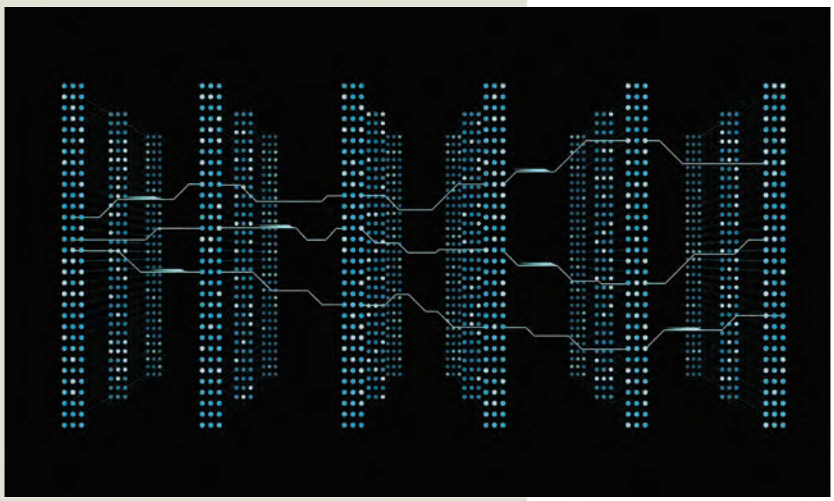
Assistant Professor Steffi Diem has been selected to serve as a U.S. Science Envoy for the Department of State in 2024. The federal program empowers leading U.S. scientists to leverage their expertise and networks with the goal of increasing international cooperation around important scientific endeavors. Diem is the first fusion energy envoy and is one of four new U.S. Science Envoys in 2024–the program's first all-women cohort.

How machine learning can accelerate the design of next-gen nuclear reactor materials

A team of researchers from UW-Madison and Indian Institute of Science has developed machine learning models that can predict changes in the mechanical behavior of materials in a nuclear reactor after they have been irradiated with neutrons.

The researchers demonstrated that these predictive models can significantly reduce the time and cost associated with conducting experiments on neutron irradiation of materials and accelerate the development of materials for advanced nuclear reactors. The team published a paper detailing its advance in October 2023 in the journal *Fusion Engineering and Design.*

In this project, the researchers focused on special type of steel called ferritic/martensitic steel because it's more resistant to damage caused by nuclear radiation. A variety of ferritic/martensitic steels can be made by changing the composition and processing conditions, and they behave differently under different levels of radiation exposures at different temperatures. Therefore, it's important to thoroughly investigate the effects of neutron irradiation on ferritic/martensitic steels to identify the most suitable option for a specific irradiation level in a given reactor.



However, future developments in ferritic/martensitic steels for advanced reactors will require neutron irradiation data, which can be challenging to obtain experimentally because of scarcity of nuclear testing facilities, and the large expenses and time commitments involved.

Kumar Sridharan

"Machine learning is extremely valuable for this application because doing neutron irradiation experiments in a test reactor and post-irradiation testing and characterization of the steels can cost millions of dollars and take about six or seven years, not to mention there are very few test reactors in the world," says Grainger Professor Kumar Sridharan, an author on the paper. "So I think this is an excellent application of machine learning with a lot of practical value."

The researchers used a large body of data from previous neutron irradiation experiments and applied machine learning concepts to predict changes in mechanical properties for future ferritic/martensitic steels. The team used an algorithm called SHAP to pinpoint the most important input parameters/variables influencing the strength of these steels upon irradiation. Using these variables, the researchers deployed four machine learning algorithms to predict the strength of different ferritic/martensitic steels subjected to varied radiation levels and temperatures.

Accelerating nuclear materials discovery through AI is key in achieving climate goals

Adrien Couet

Associate Professor Adrien Couet is creating a platform to speed up development of materials for advanced fission and fusion reactors.

The project has received $3 million in support from Schmidt Futures, a philanthropic initiative.

Developing new structural materials that can withstand the extreme environments in advanced nuclear fission and fusion reactors is a very time-consuming and costly process. "To deploy these nuclear energy technologies on a timeline conducive to reaching our climate goals for carbon-free energy, it's critical to discover, develop and license new materials at an unprecedented pace," Couet says. "This is our grand challenge."

To tackle this challenge, Couet and his collaborators will create an integrated platform for accelerated nuclear materials development. The experimental platform will combine recent and novel developments in autonomous additive manufacturing, automated characterization, and testing in extreme environments, coupled to scientifically guided artificial intelligence.

"This project has the potential to advance the state of nuclear energy research and development quite dramatically," Couet says. "Using high-throughput experiments—processing, testing and characterization—coupled to machine learning approaches is totally new in this field. And this will be the first high-throughput experimental platform for extreme environments applications."

Lianyi Chen, the Charles Ringrose Associate Professor in mechanical engineering, is co-principal investigator on the project. Chen will develop unique additive manufacturing equipment to create the alloys. Researchers at Washington University in St. Louis and Idaho National Laboratory are collaborating on the project.

"One reason I'm really excited about joining UW-Madison is because the university is one of the world's leading institutions in fusion science research and education."

FOCUS ON NEW FACULTY

Adelle Wright is bridging the gap between fusion science and real-world energy technology

In her highly interdisciplinary research, Adelle Wright brings together cutting-edge insights from plasma physics, applied mathematics and computer science to enable the development and deployment of fusion as a clean energy technology.

Wright studies magnetohydrodynamics, which describes the macroscopic behavior of magnetically confined plasma, the ultra-hot ionized gas that produces energy in a fusion reactor.

"These plasmas consist of charged particles in a fluid that interact with electromagnetic fields, so a whole range of different interactions and couplings can occur, making this nonlinear system very difficult to understand and predict," says Wright, who joined the department as an assistant professor in fall 2023. "A key goal in my research is to develop a predictive understanding of nonlinear magnetohydrodynamic phenomena, which is essential for the success of magnetic confinement fusion."

Wright's research is focused on stellarators, which are viewed as the main alternative to tokamaks for fusion reactors. Because stellarators haven't been studied as extensively as tokamaks, there's a limited amount of experimental data for these devices. To help speed up stellarator development, Wright develops tools for high-fidelity numerical simulations and leverages high-performance computing to investigate and validate stellarator designs.

"One reason I'm really excited about joining UW-Madison is because the university is one of the world's leading institutions in fusion science research and education, and it's particularly strong in the specialized area of stellarator physics, so there are many great opportunities for collaboration and to make an impact with my work," says Wright, who plans to collaborate with experimentalists who work with the NEEP department's Helically Symmetric eXperiment.

Wright received her bachelor's degree in physics and her PhD (2021) from the Australian National University. Prior to joining UW-Madison, she was a staff research physicist at the Princeton Plasma Physics Laboratory.

She has also worked at the Australian Academy of Science, first as the international science council liaison officer, then as the coordinator for international science engagement. In this capacity, she worked closely with the National Committees for Science to manage the representation of Australian science at the International Science Council and its member organizations.

In her research, Wright works at the intersection of science and policy. She examines the drivers that shape the environment into which fusion energy technologies would be deployed. For example, Wright aims to understand factors such as social license, markets, regulation and geopolitical impacts so they can be considered early in the design process, increasing the likelihood that the fusion technology would be successfully adopted.

She is especially interested in science diplomacy, in which nations engage with each other on scientific issues that support their strategic interests. At UW-Madison, Wright wants to create interdisciplinary research and educational programs focused on this topic.

"There are actually very few formal accredited programs or courses dedicated to science diplomacy," she says. "I think, particularly given the expertise of NEEP faculty as well as faculty from across the university and the highly collaborative interdisciplinary environment here, that UW-Madison is really well-placed to establish a footprint and be a leader in this area."

With UW-Madison assist, groundbreaking project could accelerate nation's clean energy transition

A first-of-its-kind energy storage system in the United States could come online soon in Wisconsin's Columbia County, and engineering faculty and staff are playing a role in making it a reality. The project would be the first to demonstrate—at a commercial scale—a closed-loop, carbon dioxide-based energy storage system and could validate the technology for wide-scale deployment in the United States.

Led by energy provider Alliant Energy, the new battery system, known as the Columbia Energy Storage Project, represents a significant advancement toward a more sustainable, reliable and cost-effective energy future. In September 2023, the U.S. Department of Energy (DOE) Office of Clean Energy Demonstrations selected Alliant Energy for a grant of as much as $30 million to construct the 200-megawatt-hour energy storage system. Pending approval, construction could begin in 2025 with completion in 2026.

The project will use an innovative design by Energy Dome, a Milan, Italy, energy storage solutions provider, to deliver long-duration energy storage by compressing carbon dioxide gas into a liquid. When that energy is needed, the system converts the liquid carbon dioxide back to a gas, which powers a turbine to create electricity. This highly efficient, zero-emissions battery system can power approximately 20,000 Wisconsin homes for up to 10 hours on a single charge.

The idea to pursue the project grew out of conversations between UW-Madison faculty and Alliant Energy leaders who are members of the college-led Clean Energy a network of industry, policy, research and community partners to co-create equitable and community-driven clean energy solutions throughout Wisconsin.

"Bringing a new technology of this scale to Wisconsin is very exciting and will create opportunities to build an economy around it here," says Thomas and Suzanne Werner Professor Oliver Schmitz, who directs the initiative and is the college associate dean for research innovation. "This technology will provide crucial storage for solar and wind energy, enabling more renewable energy use."

Energy Dome's CO_2 battery located in Sardinia, Italy. Photo courtesy of Energy Dome.

NEEP celebrates Introduce a Girl to Engineering Day

In February, the department joined in the celebration of DiscoverE's annual Introduce a Girl to Engineering Day. More than 160 participants from high schools throughout southern Wisconsin visited the UW-Madison campus to learn about career opportunities in nuclear engineering.

The day began with department facility tours, including the Pegasus-III fusion energy experiment, Helically Symmetric eXperiment (HSX), the Ion Beam Laboratory, and a virtual tour of the UW Nuclear Reactor.

Students attended a panel discussion, part of a series of diversity seminars hosted by the Nuclear Engineering Department Heads Organization (NEDHO). Assistant Professor Juliana Pacheco Duarte moderated the diversity panel, which featured Lisa Marshall, American Nuclear Society vice president/president-elect and professor at NC State University; Kirsten Laurin-Kovitz, associate laboratory director at Argonne National Lab; Tracy Radel, vice president of engineering at SHINE Technologies; and Amber Dotzler, nuclear criticality safety engineer at Paschal Solutions Inc. Students also participated in hands-on activities offered by the NEEP department, the College of Engineering, the UW-Madison ANS chapter, Solis, Engineering Summer Program, Constellation, NextEra Energy, Realta Fusion, Type One Energy, SHINE Technologies, UW-Madison Medical Physics Graduate Student Outreach Council, and Maydm.

Department of
Nuclear Engineering
& Engineering Physics

1500 Engineering Dr., Room 151
Madison, WI 53706
engineering.wisc.edu/neep

Excitement is building

Our engineering campus is getting a facelift. With formal approval of state funding for a new 395,000-square-foot building, we're continuing our growth initiative.

The seven-story building will span parts of the existing Engineering Mall and the space currently occupied by 1410 Engineering Drive (which will be demolished), and feature refreshed green space and indoor and outdoor gathering spaces.

The $347 million facility, funded through $150 million in private giving and $197 million from the state of Wisconsin, will be a catalyst for research while allowing the college to educate many more exceptional students.

Explore more, follow along with the building's progress, and support the project at engineering.wisc.edu/new-building.

All images by Continuum Smithgroup. Artist's concepts of the new building.