COLLEGE OF ENGINEERING

Momentum!

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Exploring the Water-Energy Nexus

Oregon State UNIVERSITY

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FRONT COVER
Retrieval of a TRIAXYS™ wave measurement buoy at the end of the summer 2013 deployment. Shown are marine technicians Walt Waldorf (front), Tully Rohrer (center), NNMREC faculty Sean Moran (left), Ean Amon (right), and graduate student Josh Baker (rear) (Photo by Dan Hellin).

BACK COVER
Ocean Sentinel recovery operations at the end of the summer 2013 deployment. Shown are NNMREC faculty Ean Amon (left), Sean Moran (center), and graduate student Josh Baker (right) (Photo by Dan Hellin).

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College of Engineering faculty and staff gathered at Reser Stadium for the 2013 Fall Awards Breakfast.

The water-energy nexus

Energy production using today's fossil-fuel-based technologies demands massive amounts of water. Likewise, processing and diverting water require lots of energy. As the world faces the realities of population increases, developing economies, and climate change, properly managing these resources becomes one of the most critical tasks we face.

Researchers at the College of Engineering are collaborating across diverse disciplines to contribute knowledge and technologies at the water-energy nexus. In this issue, you'll read about several of these innovative projects and how they are moving the science forward.

- Oregon State University is taking leadership in the search for wave energy technologies, and two stories in this issue address pieces of this major undertaking. Research is underway to determine how and where to deploy wave energy converters for maximum efficiency and minimal impact to the shoreline. Also, the 2013 deployment of the Ocean Sentinel — a wave energy testing platform — provided an opportunity to study the integrity of its mooring system; a more sustainable, longer term solution to prevent biofouling; and how the presence of wave energy devices could affect life on the sea floor.
- Two separate, cross-disciplinary teams are looking for ways to offset fossil-fuel consumption by turning microbes into biofuels. One study uses algae as a microbial source and seeks to understand how certain technology choices impact water use in algal biofuels processing.
- Another team is developing tools that will help engineers determine where in developing countries to site micro hydroelectric plants. Their solution will also help farmers and others respond to changing water resources.
- And finally, understanding the fundamental mechanisms that underpin technologies for capturing and storing carbon dioxide could help to mitigate greenhouse gas emissions in the short term and go a long way toward protecting Earth's aquifers. One of our accomplished faculty was chosen to take her research to international audiences during 2014 as part of the Henry Darcy Distinguished Lecture Series in Groundwater Science.

These researchers and many more are seeking ways to help us be better stewards of our precious resources. Simultaneously, they are staying true to our mission of educating the Oregon State Engineer.

The Oregon State Engineer belongs to a unique class of engineers who possess a strong technical foundation coupled with well-developed leadership skills and a broad worldview. We give our students opportunities to participate in research as early as their freshman year, enabling them to integrate book learning with experiential opportunities, theory with practice, and fundamental knowledge with new discoveries. Our students are eager and able to play valuable roles in helping us learn how to be good resource stewards. Their future, and the future of their children, depend on it.

Go Beavs!

Scott A. Ashford, Ph.D.
Kearney Professor and Dean
Oregon State University
College of Engineering

Professor Annette von Jouanne, on board the Pacific Storm, prepares for the first deployment of the Ocean Sentinel testing platform in August 2012.

Staking a claim in wave energy research

By Marie Oliver

Ocean currents as far away as Japan create the waves along Oregon's approximately 350 miles of rugged and scenic coastline. The immensely potent Pacific Ocean never ceases moving, regardless of the time of day, the season of the year, or the weather.

Harnessing power from this continual motion is not a new idea. But the world's increasing hunger for sustainable energy solutions has researchers scrambling to discover innovative and Earth-friendly solutions for moving ocean-generated energy onto the grid.

Contributing to the development of renewable energy sources is a high priority for Oregon State University's College of Engineering. "We really need to fully explore all forms of alternative renewable, fuel-free energy," said Annette von Jouanne, professor with the School of Electrical Engineering and Computer Science.

Von Jouanne, her colleagues, and numerous student cohorts have been working hard for the past 16 years to ensure that Oregon and the United States claim leadership in wave energy research.

A perfect storm of location, facilities, people

Oregon State and its affiliated facilities are uniquely located and equipped for this type of research. Although Oregon's coast represents less than one percent of the world's coastlines, its characteristics make it innately suitable for this work. "It's always the West Coast of land masses that have the strongest wave energy potentials, because global winds travel from west to east," said von Jouanne.

On the Corvallis campus, the Wallace Energy Systems and Renewables Facility (which von Jouanne co-directs) is the highest capacity university-based energy systems laboratory in the nation, and the O.H. Hinsdale Wave Research Lab houses some of the largest wave basins in North America. "All of our scaled laboratory facilities help energy developers go from the modeling stage to small-scale prototype development," said von Jouanne.

Fifty-two miles away in the coastal town of Newport, the Hatfield Marine Science Center provides ready access for instrument deployment and retrieval, plus abundant opportunities for environmental impact studies.

Thanks in large part to von Jouanne's consistent approaches to Congress over the years, investments at the federal level have enabled the university to significantly boost wave energy research efforts. In 2008, U.S. Department of Energy funding birthed the Northwest National Marine Renewable Energy Center. Housed on campus under the direction of Belinda Batten, the NNMREC (pronounced "Nim-rek") is one of only three such centers nationally. The NNMREC's mission includes conducting wave energy and tidal energy research, providing test sites and facilities for prototype devices, and assisting developers with planning and permitting activities. It is a collaborative venture with the University of Washington, which focuses on tidal energy.

Ocean Sentinel deployments

After proof-of-concept tests in 2007 and 2008, Oregon State engineers completed a mobile sea-worthy platform in 2012 called the Ocean Sentinel. It is designed to allow researchers to test scaled (up to 100-kilowatt) wave energy devices and has been deployed twice so far.

In late summer 2012, researchers used the platform to perform a six-week test on a wave energy converter prototype called WET-NZ (Wave Energy Technology–New Zealand). Although the device was not connected to the grid, the Ocean Sentinel allowed researchers to work with it as if it were. The Ocean Sentinel measured and recorded power output from the WET-NZ device, collected and stored data transmitted from a wave-measuring buoy moored nearby, conducted environmental monitoring using onboard instrumentation, and wirelessly transmitted collected data to a station on shore.

Because no device manufacturers were ready for testing in 2013, the NNMREC decided to conduct studies using just the Ocean Sentinel. One graduate student, Josh Baker ('13 M.S. Civil Engineering), used the opportunity to explore the effects of ocean waves and currents on the mooring system. Another, Malachi Bunn, tested an environmentally friendly method to prevent corrosion and biofouling. A faculty researcher, Sarah Henkel, studied how the presence of the test platform's anchoring system affects life on the ocean floor.

Josh Baker: Testing the mooring lines

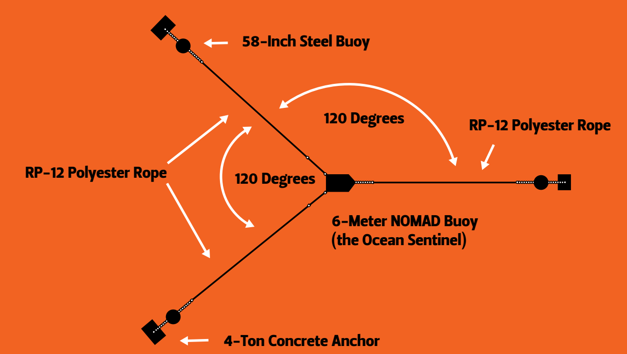
The fact that there was no wave energy device being tested in 2013 allowed the NNMREC to focus on the Ocean Sentinel's mooring system. Baker took the opportunity to complete his master's thesis under the direction of Solomon Yim, the Glenn Holcomb Professor in Structural Engineering. A computer model had been used to design and test the first iterations of the system, and several changes were made to it before the Ocean Sentinel was deployed in 2012. Baker's first task was to update the model to more accurately represent the deployed configuration. His second task was to gather real-world data that could be used to characterize the behavior of the mooring system in various ocean conditions, and compare those data to model simulations.

The mooring system uses three lines in a triangular configuration; one drops off the bow and the others drop off each corner of the stern. Each line connects to an 8,500-pound concrete anchor that sits on the sea floor at a depth of about 150 feet.

"The mooring system is designed to keep the Ocean Sentinel within an imaginary boundary called the watch-circle," said Baker, an active-duty lieutenant with the U.S. Navy Civil Engineer Corps. "You want the watch-circle to be small to prevent the Ocean Sentinel from running into the wave energy device being tested, which requires tight mooring lines. However, the mooring lines should also be loose enough for the Ocean Sentinel to ride over large waves."

Load cells — electronic instruments used to determine how much force each mooring line is subjected to — are

The Ocean Sentinel's mooring system



Josh Baker stands next to a TRIAXYS™ wave measurement buoy during the 2013 deployment.

installed between the Ocean Sentinel and each mooring line. They are then connected via instrumentation cables to computers onboard the Ocean Sentinel, where the real-time tension force on each mooring line is recorded.

Simultaneously, a TRIAXYS™ Directional Wave Buoy measures environmental data. It logs information about the waves, including how big they are, what direction they are coming from, and how often they pass through. It also captures data about the current: how fast it is moving and in what direction. The data are sent wirelessly from the TRIAXYS™ to the Ocean Sentinel.

"The benefit is that you have all of this environmental data for the site throughout the deployment, and you're able to couple it with the tension-force data," said Baker. "Then you can compare the results to the design specifications of the mooring system and see how it performs."

Typhoon Pabuk off the coast of Japan in September 2013 provided a perfect opportunity to test the mooring system's limits. Thirty- to 40-foot waves off the Oregon coast caused the Ocean Sentinel to drag its anchors along the ocean floor and move out of its watch-circle.

"That's a bad thing — you don't want that to happen," said Baker. "But it did happen, and it was actually a great time for this type of failure. The Ocean Sentinel was out there by itself, and it moved only about 400 feet. If we had been testing a wave energy device, it could have been a real issue. But it ended up being a very useful study, because it showed the limits of the Ocean Sentinel's current mooring system without any major consequences."

Baker's preparation for testing the mooring system began well before the Ocean Sentinel was deployed. He worked with NNMREC faculty Sean Moran and Ean Amon to determine which load cells to use, where they should be installed, how to connect them to the mooring lines, and how to connect them to the computers. He was the lead graduate student aboard the R/V Pacific Storm — Oregon State's retrofitted trawler — during deployment.

After several weeks of data were collected, Baker analyzed and interpreted the output, then made some preliminary comparisons to simulations using the updated computer model.

"The model provided fairly accurate results in some areas, but it was way off in others, so the computer model needs some work," said Baker. "And that's not an abnormal thing — that your field conditions cannot be predicted exactly by a computer model — you're going to see a margin of error." Another graduate student will build on Baker's work to fine-tune the model and improve its accuracy.

Malachi Bunn: Looking for biofouling solutions

Although the September storm was a boon to Baker's research project, Bunn wasn't so lucky. Bunn, who is pursuing a Ph.D. in the School of Chemical, Biological and Environmental Engineering under the guidance of Associate Professor Alex Yokochi, has been lab testing a method for preventing biofouling — the unwanted accumulation of organisms, algae, plants, and animals — at the Hatfield Marine Science Center. He wanted to take advantage of the Ocean Sentinel's deployment to subject his antifouling method to a real-world test.

"The ocean is what can be considered an extreme environment," said Amon, assistant professor in the School of Electrical Engineering and Computer Science, who was instrumental in developing and deploying the Ocean Sentinel. "Saltwater is very corrosive, and it's a very live environment. Every time we pull equipment back out after even just a few months, it's surprising how much growth there is on everything — everything from green slime all the way up to small-sized barnacles and kelp. So having devices out in that environment that have moving parts and can become entangled and bound up by growth makes the anti-biofouling coatings and other measures extremely critical for their success."

Bunn is recycling an idea that has been in the literature for a couple of decades. He mixed graphite powder, which is extremely electrically conductive, into polyurethane paint, and applied an electrical charge to it. "The voltage causes a chemical reaction that generates a small amount of bleach at the surface, and the bleach prevents barnacles and algae from growing," he said.

He believes that this is a solution whose time has come. "The idea has been out there for a while, but it's been largely discounted," he said. "People think it's complex. They think the electronics are expensive, but in 2014, our electronics are significantly cheaper than they were in the mid-1990s, so that cost is mitigated. A wave energy buoy is already generating electricity, so no added battery system or power generation is required — you just take off a tiny bit of that power to provide the energy to run the system. So a lot of the concerns people have had for implementing this are not really applicable."

Antifouling coatings used today contain copper oxide and organic biocides, which are toxic to marine life, and they have relatively short life spans. "You've got somewhere in the range of three to five years at the most with any of those kinds of paints," said Bunn. "But with the electrochemical antifouling, you never run out, assuming that the paint doesn't break down, which is one of the things I'm studying. So you don't have to take in your wave energy device — you can just leave it until some other source of failure occurs."

Although bleach in large quantities might be harmful to ocean life, Bunn said that the small amount created using his antifouling method is easily and quickly dispersed, and it is not an environmental concern.

Bunn applied his electrically conductive paint to some plastic slabs and hung them off the side of the platform last summer. "Unfortunately, I don't have a whole lot to say about the results of that, because the extreme storm ripped off the plates," he said.

But he's not giving up. He expects to have another opportunity to try again.

Ph.D. candidate Malachi Bunn applies a conductive paint made from polyurethane and graphite to a plastic plate in preparation for a test of the electrically driven anti-biofouling system.

Sarah Henkel and Kody Robinson, co-captain of the R/V Elakha ("Sea Otter"), wrangle a Giant Pacific Octopus captured in a beam trawl at the site. The beam trawl is used to survey larger organisms living on the surface of the sediment to complement the grab samples.

Sarah Henkel: Surveying ocean life at the test site

Henkel, assistant professor in the Department of Zoology and senior researcher at the Hatfield Marine Science Center, specializes in the biological effects of wave energy device installations. She has been conducting a variety of benthic surveys — studies of life on the ocean floor — since 2010.

Henkel was excited about leaving only the mooring system in place over the past few months. Her team uses a 500-pound device with jaws that grab a square of sediment from the sea floor, and getting too close to the anchors during the 2012 deployment could have put the platform and the wave energy device they were testing at risk.

"Now I can do sampling very close to the anchors without being worried about my gear getting tangled up with the expensive equipment," she said. "This has been an opportunity for me to look for potential changes to the benthic system very close to the mooring system."

Henkel's team was able to get the first samples close to the anchors in October 2013 and April 2014. They analyzed the grain size of the sediment and identified and counted all organisms living in the sediment.

Results are preliminary, and Henkel has not drawn any firm conclusions. She was not surprised to notice some scouring around the concrete anchors, where the finer sediment particles had floated away. "It's a situation that bears watching in the future because it could affect the communities of organisms that populate the nearby area," she said. "When we get half a kilometer away from the anchors, we can't detect any changes, so the effects are extremely localized, and it's unlikely to have population-level effects on organisms or on any predators that might feed on the organisms that live in the sand."

The question becomes scaling up. "When you deploy one device, you get a very localized effect. But if you were to deploy tens or hundreds of devices, each one with a small sphere of influence, they could potentially start overlapping and cause population-level impacts," she said. "That's what remains to be seen."

Henkel hopes to take more samples this summer before the mooring system is removed. **M!**

Professor Dorthe Wildenschild discusses a new approach to rock sample saturation with research associate Linnéa Andersson.

The fine art of trapping carbon emissions

By Thuy T. Tran

Unraveling the tangled and politically charged threads of global climate change — fossil fuel consumption, economic health, and the progress of renewable energy — requires a comprehensive portfolio of research efforts. Dorthe Wildenschild, professor in the School of Chemical, Biological and Environmental Engineering, is advancing the fundamental science that underpins carbon dioxide (CO_2) capture and storage (CSS) — also known as sequestration.

CSS technologies capture CO_2 that power plants and other large industrial sources would otherwise release into the atmosphere. They compress the CO_2 into its supercritical (fluid) state and inject it deep underground, often a mile or more below aquifers and beneath geologic structures.

This year, Wildenschild has been sharing her work at universities around the world as part of the Henry Darcy Distinguished Lecture Series in Groundwater Science. She enjoyed bringing her lecture back home to Oregon State in mid-April, where it was a relief for her to once again encounter familiar faces and classrooms. As a 2014 Darcy Lecturer, she will have delivered 38 seminars in 37 cities in eight countries by the end of the year.

Once supercritical CO_2 is injected underground, four mechanisms can take place: structural trapping, solubility trapping, mineral trapping, and capillary trapping (also called residual trapping). Among these, Wildenschild sees the most promise using capillary trapping, and she is looking for ways to optimize the method.

Because supercritical CO_2 is usually less dense than underground brine (subsurface water containing high concentrations of dissolved mineral substances), supercritical CO_2 will migrate up until it hits an impermeable rock and, hopefully, stay there. This is called structural trapping, but it's not a perfect solution.

"The problem comes in when there's a geologic fault or an old well bore," said Wildenschild. "The CO_2 can then migrate upward, acidify aquifers, and make the groundwater undrinkable."

In the best-case scenario where the supercritical CO_2 does remain trapped, the hope is for it to slowly dissolve (called solubility trapping), sink, and eventually precipitate out as carbonate minerals (called mineral trapping).

"That is the ultimate sequestration," said Wildenschild. "But, given the kinetics of the dissolution, and particularly the mineralization, we're talking about thousands of years. It's not going to solve the problems for us here and now."

Wildenschild's research focuses on capillary trapping. This method involves injecting supercritical CO_2 into a porous underground medium (see illustration). The underground brine is pushed out of the way, only to return when the injection stops, and capillary forces hold the CO_2 in tiny clusters in the pore space.

"It's basically like holding liquid in a straw, and because of the interfacial tension (capillary forces), the CO_2 can't go anywhere," said Wildenschild. "To me, that provides a lot more security than having to rely on a stratigraphic trap not being compromised. The other advantage is that the CO_2 is distributed in many tiny little pores instead of one large volume, significantly increasing the surface-to-volume ratio, and making the dissolution and precipitation steps go much faster."

Wildenschild mimics different injection scenarios in the lab by varying parameters such as pressure, temperature, salinity, flow rate, and volume. She uses x-ray microtomography, a technique similar to CAT scanning that yields 3-D information on the internal features of an otherwise opaque medium. The technique allows her to "see" inside the pore space in order to fully understand and maximize capillary trapping efficiency.

Her experiments are carried out at the Advanced Photon Source at Argonne National Laboratory, a national user facility with the brightest x-ray photon beams in the western hemisphere.

"We use synchrotron radiation to see more, and better, and faster," said Wildenschild. "It's like CAT scanning on steroids."

Wildenschild's research is unique in the field, because it provides an understanding about how things work at the level of individual fluid-to-fluid interfaces.

"We put a lot of emphasis on generating really, really accurate data at very small scales," she said. "I think we are probably the only group that has done imaging with x-ray microtomography at a very small scale in a synchrotron environment, and controlling as many variables as we do."

Results so far indicate that the injection can be manipulated to maximize the amount of supercritical CO_2 trapped. The size and local connectivity of the tiny pores affect subsequent dissolution and mineralization mechanisms.

Among fossil fuels, coal is the major culprit in global CO_2 outputs. Coal plants make up the largest source of greenhouse gas pollution in the United States, and China consumes nearly as much coal as the rest of the world combined.

"People are going to continue to use coal as long as it's there and it's cheap," said Wildenschild. "Coal is not going away until there are alternative energy sources that are as cheap. We need a bridging solution that deals with CO_2 emissions, yet doesn't destroy our water resources."

Wildenschild hopes that the fundamental understanding of how small-scale capillary trapping takes place will ultimately lead to implementation recommendations for actual large-scale injection processes, and thus advance efforts to address climate change at a global level.

"The dream is to find something by looking at these tiny pores that will help to figure out how to store CO_2 in the most secure way," she said. "I hope to contribute to solving the short-term problem."**M!**

Professor Dorthe Wildenschild, research associate Linnéa Anderson, and Ph.D. candidate Anna Herring discuss thermocouple readings providing the temperature record for their supercritical CO_2 sequestration setup.

An x-ray microtomography image of a sandstone rock, showing a 3-D cutout of the sample. Trapped supercritical CO_2 clusters are highlighted in yellow.

Using microbes to make biofuels

By Warren Volkmann

Greenhouse gasses respect no borders as they waft around the globe. Carbon dioxide (the headliner) and methane (its lesser-known, but more potent sidekick) challenge researchers all over the world to work together to find a solution to global warming.

Chemical, biological, and environmental engineers at Oregon State University are collaborating among disciplines to develop new processes that use microbes to convert greenhouse gasses to fuel and beneficial products.

A methane bioreactor

A one-year grant from the Department of Energy is funding the development of a bioreactor that can turn methane (natural gas) into a liquid fuel that can be transported and pumped like gasoline. The $631,000 grant came through the Advanced Research Project Agency–Energy (ARPA–E).

"Currently, there are no commercially viable biological approaches to convert methane into a liquid fuel," said Lewis Semprini, distinguished professor of environmental engineering. Semprini is working with Mark Dolan, an environmental engineer who knows how to keep methane-eating bacteria alive and well fed; Goran Jovanovic, a chemical engineer who is designing the bioreactor; and Karl Schilke, a biological engineer who is working on immobilizing the bacteria in a biofilm.

The team is designing a bioreactor with a stack of plates (the lamina) that are infused with methane-eating bacteria called *Methylosinus trichosporium OB3b*. The biomechanics of the system are simple: methane and oxygen are piped into the bioreactor and flow between the plates, which create a very large surface area for gas exchange. The microbes do what their kind has done for millions of years: take in the single-carbon methane gas and, in its first step of utilization, convert it to liquid methanol.

"We are trying to trick these microbes into stopping their utilization processes at methanol, instead of converting the methane all the way to carbon dioxide," Semprini explained. "Another challenge is to extract the liquid fuel without putting a lot of energy into the system. Our bioreactors have to be very energy efficient."

Oil fields roar day and night with giant plumes of burning methane because there is no pipeline to carry the methane gas, but an on-site bioreactor could convert that wasted jet of methane into fuel. This methane-to-liquid-fuel bioreactor could be transported to remote locations, including oil fields in desert areas, frozen tundra, and deep water.

Other ARPA–E projects are trying to genetically engineer methane-eating bacteria to make a four-carbon alcohol called butanol, which has a higher energy density than methanol. If these researchers are successful, the new strain of microbes can be seeded into the bioreactor to make butanol.

Biofuel from algae

First-generation biofuels are relatively simple: they use yeast to break down starch from corn to make ethanol, which can be added to gasoline. Second-generation biofuels come from biomass, such as wood and corn stalks. Third-generation biofuels, which have been under development for the past decade, extract fuels from algae, or in some fashion use carbon dioxide as a starting point.

Oregon State researchers are receiving a four-year, $2 million grant from the National Science Foundation's Emerging Frontiers in Research and Innovation program to focus their efforts on algal biodiesel, a third-generation biofuel. This research project uses algae — another type of microbe — to pull carbon dioxide directly from the air using photosynthesis.

"Algal fuels are a possible solution in the quest to find nonfossil fuels," said Christine Kelly, associate dean for academic and student affairs and one of the principal investigators on the project. "Algae take carbon dioxide from the atmosphere, instead of mobilizing it from the subsurface like petroleum fuels. This is why algal biofuels are potentially better environmentally."

The system will use a specific type of algae, classified in a group called diatoms, which have a stiff but flexible body made of chitin — the same material found in the shells of insects, crabs, and lobsters. The diatoms will be grown in water enriched with carbon dioxide. The algae use photosynthesis to convert the carbon dioxide into lipids that can be easily converted to biodiesel.

Kelly is working on the project with Greg Rorrer, who spearheaded the program and is now at the National Science Foundation. J. Antonio Torres of Oregon State's Department of Food Science is working on how to extract the lipids and useful byproducts from a watery mash of diatoms. Bettye Maddux of the Department of Chemistry is also a principal investigator.

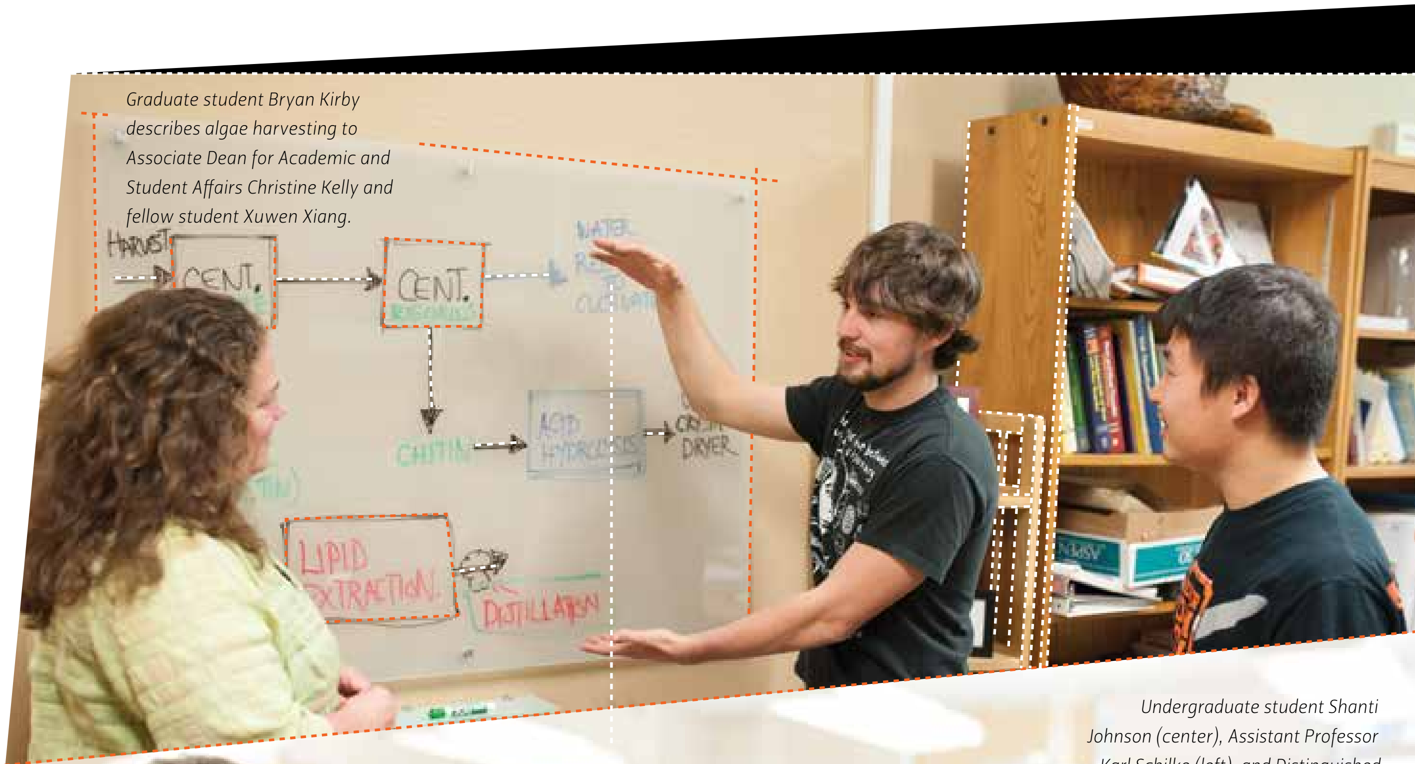
Kelly, Rorrer, and Torres are working to create lab-sized prototypes of portions of the system that may one day result in a commercial-scale biofuels refinery. For her part, Kelly is performing a technical economic analysis and lifecycle analysis to determine how the process can be implemented on a commercial scale.

The lifecycle analysis includes the impact of water use in the production of the algal biofuels and illustrates the inextricable tie between two vital resources: water and energy.

Besides the biofuel, the process yields two high-value products: chitin and glucosamine. The chitin from the diatoms' cell walls is ideal for making hemostatic bandages to manage bleeding during emergencies. Glucosamine is a valuable nutrient that is popular with athletes and physical therapists for its beneficial effects on bones and joints.

In the final steps of the process, lipid and chitin will be removed from the diatom debris, which will then be treated by anaerobic digestion to recycle nutrients and generate methane gas.

If both of the engineering programs succeed, the methane produced by the Kelly-Rorrer-Torres-Maddux biofuel plant could be piped into the Jovanovic-Semprini-Dolan-Schilke bioreactor, transforming a potent greenhouse gas yet again into something useful, creating a never-ending cycle of carbon re-use. **M!**

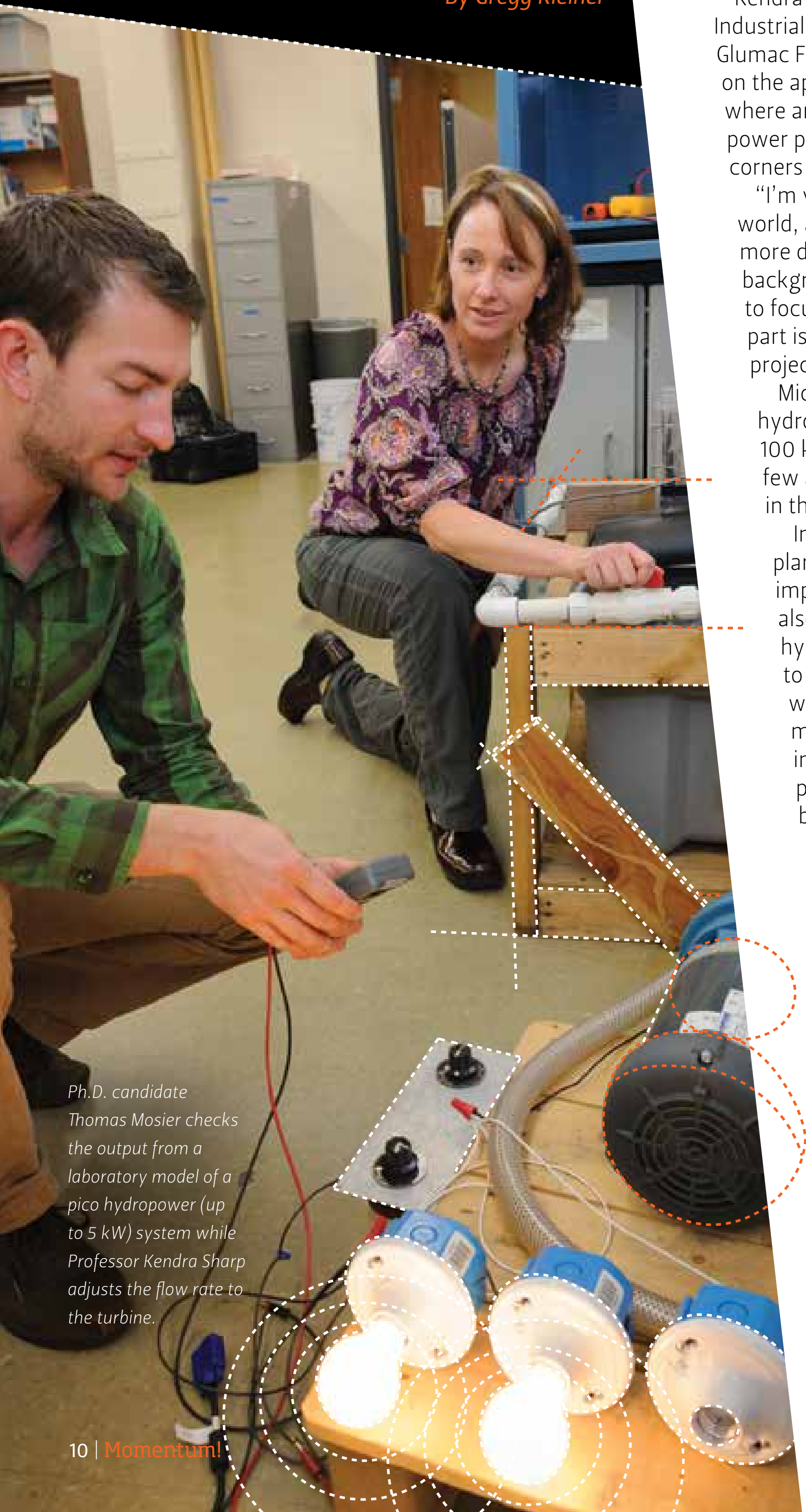


Graduate student Bryan Kirby describes algae harvesting to Associate Dean for Academic and Student Affairs Christine Kelly and fellow student Xuwen Xiang.

Undergraduate student Shanti Johnson (center), Assistant Professor Karl Schilke (left), and Distinguished Professor Lewis Semprini (right) examine the immobilized bacteria cells (Methylosinus trichosporium Ob3b) they collected from a biofilm reactor to measure methane and methanol concentrations.

Teaming up to improve micro hydropower and water resource management

By Gregg Kleiner



Ph.D. candidate Thomas Mosier checks the output from a laboratory model of a pico hydropower (up to 5 kW) system while Professor Kendra Sharp adjusts the flow rate to the turbine.

As the world prepares for climate change to impact snowpack and rainfall — which will, in turn, impact water levels and stream flow — two Oregon State engineering professors and a standout graduate student are developing tools that promise to successfully site micro hydroelectric plants in developing countries and to help farmers and others respond to changing water resources.

Kendra Sharp, professor in the School of Mechanical, Industrial, and Manufacturing Engineering and a Glumac Fellow in Sustainable Technologies, works on the application side of micro hydro, researching where and how to install the small, stream-based power plants that bring light, refrigeration, and ice to corners of the earth with no electricity.

"I'm very interested in energy in the developing world, and the ways our research can have a more direct societal impact," said Sharp. "My background is in fluid mechanics, so it makes sense to focus on micro hydro, but the societal impact part is one of the main things driving me on a project like this one."

Micro hydro generally refers to small hydroelectric power plants that generate up to 100 kilowatts (kW) of electricity, Sharp said. As few as two kilowatts can make a huge difference in the lives of people in a small village.

In her research, Sharp looks for places on the planet where micro hydro is currently being implemented with good results, like Nepal. She also searches for locations with good micro hydro potential — villages with no access to power, but in close proximity to flowing water and enough elevation drop to make micro hydro possible. These places are often in mountainous regions, where bringing in power using traditional infrastructure can be challenging.

But in order for micro hydro to be successful, engineers need to know if stream flow will be sufficient to power the plant most of the year, and reliable stream flow data are often nonexistent in certain isolated areas. This is why David Hill, associate professor in the School of Civil and Construction Engineering, is collaborating with Sharp. He and doctoral candidate Thomas Mosier are developing quantitative tools for predicting stream flow in data-poor regions of the world in order to better assess site suitability for micro hydropower.

"If you're interested in developing a micro hydro site, you need information on watershed characteristics, runoff, precipitation, temperature, and all those variables that are going to help predict what the potential yield might be," Hill said. "The main inputs to prediction of stream flow on any physical scale are weather data, but getting weather data on the resolution that's appropriate for a small-scale hydro project can be difficult."

Associate Professor David Hill and Ph.D. candidate Thomas Mosier discuss the effects of terrain, glacier cover, and weather on stream flow.

Although climate modelers generate temperature and precipitation variability results, the data are often too coarse to be of use when engineers need to zoom in on small streams in mountainous terrain. So Mosier, a former Peace Corps volunteer to Kenya, has developed novel ways to convert existing global weather data to a very fine spatial scale.

"Thomas has developed algorithms that will basically do this for anywhere you want, globally," Hill said. "He's produced codes and associated data sets so that anyone can acquire his programs, specify a region of interest, obtain these high resolution monthly weather grids, and use them as input to whatever stream flow model they might want to use."

While Mosier's research has been focused on developing tools for use in Pakistan, a lot of his work is broadly applicable in other areas, Sharp said. "This is illustrated in the tools he has developed that provide precipitation and temperature on a one-kilometer grid over any global land surface," she said. "He's distributing those data via the OSU website, globalclimatedata.org."

So far, Sharp and Hill's research has been funded mainly by a $50,000 Catalyzing International Collaborations seed grant from the National Science Foundation (aimed at furthering the collaboration with the Centre for Energy Systems at the National University of Science and Technology in Pakistan), and a Graduate Research Fellowship from the Oil Spill Recovery Institute.

"We've used that seed funding very effectively," Sharp said. "The traction per dollar on that grant has been very high, and Thomas is excellent, so he's really helped us move things along."

Mosier, who is a dual-major Ph.D. candidate in water resources engineering and mechanical engineering, is one of only three Oregon State students to receive an Evans Family Fellowship, set up by Dick ('69 B.S. Industrial Engineering) and Gretchen ('69 B.S. Elementary Education) Evans to support graduate work in humanitarian engineering.

Although currently focused on micro hydro, both Sharp and Hill are excited about the potential to apply their research to other areas worldwide, including helping to predict and respond to changes in water resources triggered by climate change.

"Imagine scenarios 50 years out in places where runoff is currently modulated by snowpack," Hill said. "The net precipitation might be the same, so the net runoff would be the same, but the timing of that runoff could change dramatically if late winter warms significantly and water currently stored in the snowpack and released over months runs off almost immediately."

This lack of buffering due to the disappearance of snowpack as a storage reservoir could be a concern not only for agriculture and power generation, but also for flood control and municipal water use, Hill said.

"One of the reasons I'm excited about the project is that I can see the wider applications," said Sharp, who is currently working with the NGO Green Empowerment to generate data they can use for a site in Peru. "Our work can be applied all over the world, including Oregon." **M!**

Coastal engineers help harness waves without harming shore

By Warren Volkmann

Every winter, across the vast open reaches of the north Pacific, one of the greatest energy systems on the planet comes online. As the northern hemisphere tilts away from the sun, the jet stream shifts south, sending howling storms down across the Bering Sea.

Driven by gale-force winds for thousands of miles, the ocean that was named for its calmness — Pacific — is transformed into a rolling, roiling seascape. Enormous swells roll out far beyond the storms that spawned them, sustained by their immense momentum until they crest and crash onto the Northwest coast.

Their unpredictable arrival on the Oregon Coast is greeted with elation and trepidation. Big wave surfers from around the world converge on Lincoln City, but only the very best dare to challenge the epic surf. Nelscott Reef, — a shallow bank about a mile offshore, trips the racing swells and forms picture-perfect walls of water that stand as high as five-story buildings. The immense breakers toss giant driftwood logs like toothpicks and can reshape entire beaches in a few days.

If the energy of the waves could be captured, the power of these winter storms could light up every community on the Oregon Coast, according to wave energy researcher Merrick Haller of Oregon State University's College of Engineering. But just the thought of trying to harness all that power leaves Haller shaking his head in thoughtful wonder.

"The idea is to design wave energy technology that can survive those waves," he said. "The challenge is to withstand the winter so that energy can be generated throughout the year. You don't want to have to retrieve your equipment every time there is a bad storm."

As part of the college's Coastal and Ocean Engineering program, Haller directs research on how and where to deploy arrays of power-generating buoys, referred to as wave energy converters, or WECs. He studies not only the impact of the waves on the buoys, but also the potential impact of the buoy arrays on the nearby shore.

Although winter storms can carve up the Oregon beaches in just days, Haller is studying how rows of wave energy converters a few miles offshore might alter the shoreline over months and years.

"We are looking at how arrays change the distribution of wave energy on shore," he explained. "If you create an area of smaller waves, you might induce unnatural currents — like rip currents that flow out from the beach. That might change sediment transport, either eroding or accreting the shoreline. We are trying to provide a design tool that will help wave energy developers avoid this situation."

Haller is joined in this work by master's degree candidate Annika O'Dea, a Sea Grant Scholar who came to coastal engineering from oceanography. Born in Japan but raised in Bloomington, Indiana, Annika attended Vassar College in New York, where she majored in biology. Her international studies began in her junior year with a semester in Madagascar. After graduating, she spent a year studying French in France, and then enrolled in a master's program in oceanography at the University of the Mediterranean in Marseille. She completed the master's with an internship in Senegal, where she studied sustainable fisheries in connection with a USAID-funded project that was developed by the University of Rhode Island's Coastal Resources Center and implemented locally by the World Wildlife Fund.

While scouting for her internship, O'Dea came across a list of coastal engineering firms.

"The more I learned about nearshore processes, the more interesting I found it," O'Dea explained via email from Scotland, where she had been invited to attend the Environmental Interactions of Marine Renewal Energy Technologies conference. "I had never thought of this as a potential career path, but I started looking into coastal engineering master's programs almost immediately.

O'Dea was attracted to Oregon State because several professors are doing research she finds interesting. "I liked the location, and the program had a really good reputation," she said. "Also, my grandfather is an alumnus of the OSU College of Engineering, so I have family ties to the school."

O'Dea brought her knowledge of oceanography to Haller's team and set about analyzing the shoreline impacts of wave energy converters. Since the converters extract energy from ocean swells, the waves behind the arrays are smaller — an effect referred to as a "WEC shadow." O'Dea studied how the distance from the shore and the space between converters affected the shadow.

"What we learned was that there are many factors influencing the WEC shadow," she explained. "The most significant changes in the nearshore wave climate will occur when WEC arrays are located close to shore, when there is little space between devices, and with high-energy swell conditions."

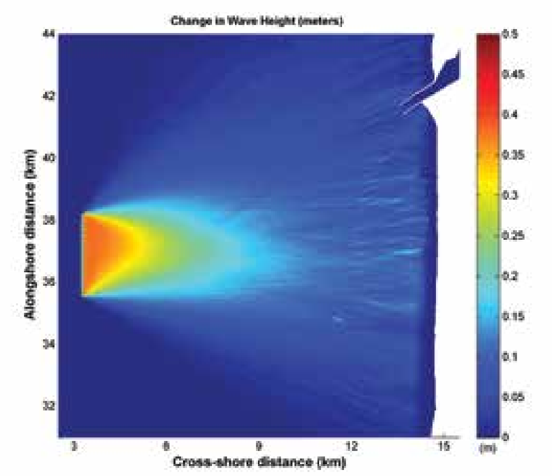
O'Dea presented her first findings last fall at the American Geophysical Union conference in San Francisco. In April, she presented a paper — *Analysis of the Impacts of WEC Arrays on the Nearshore Wave Climate* — at the Marine Energy Technology Symposium in Seattle. A journal article is in the works.

Haller put her research into context: "Annika's research is definitely of interest to the energy industry. If you are evaluating sites to put out an energy array, this is the kind of research you are looking for. What Annika has done is to identify a better threshold for environmental impacts. Her approach is quantitative. That is new. Using her computer modeling, you can determine the impact of an array on the nearby shoreline."

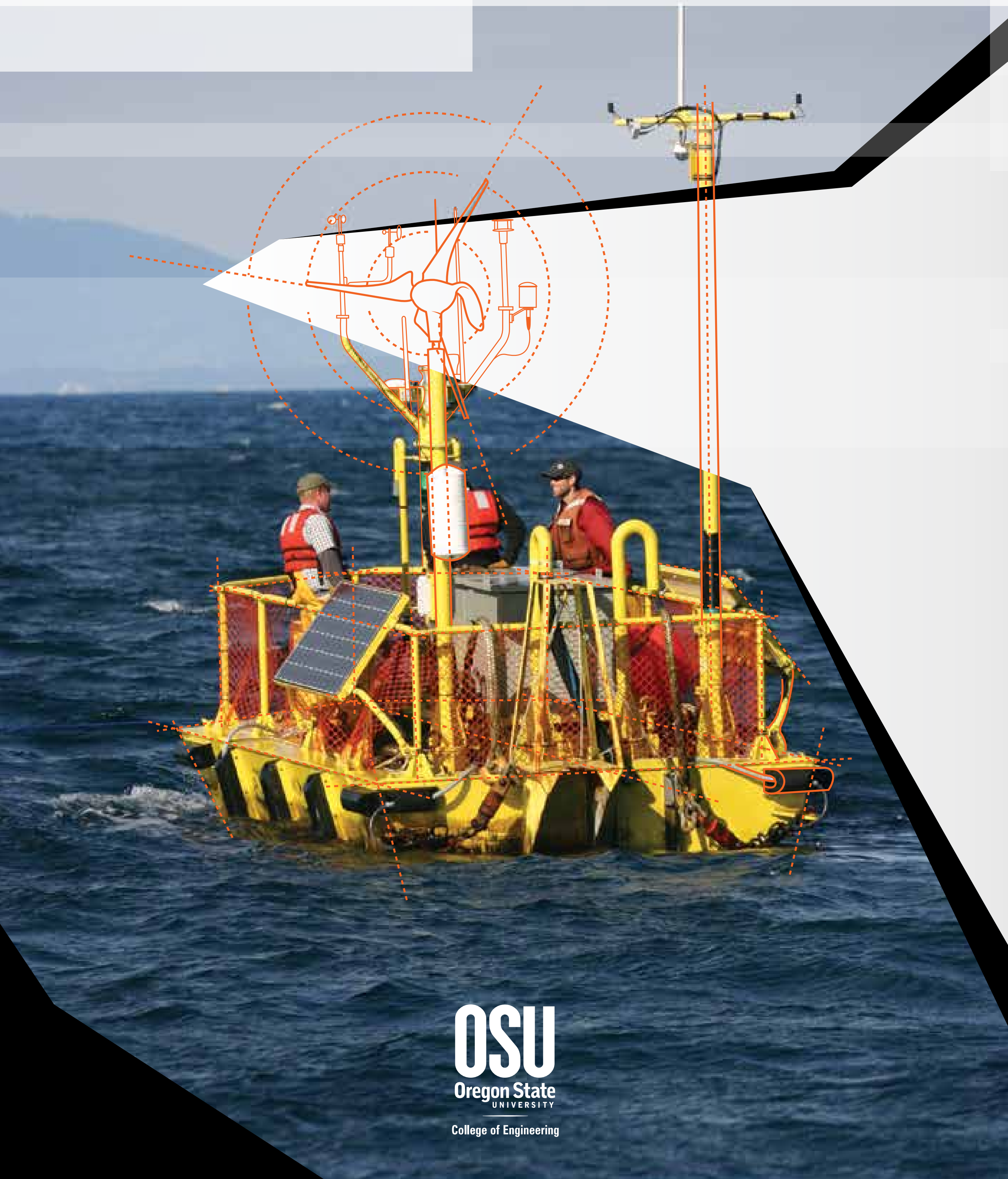
O'Dea's computer modeling will be put to a real-world test at the Pacific Marine Energy Center test grids located offshore near Newport. The Northwest National Marine Renewable Energy Center will manage the testing.

Meanwhile, O'Dea will be embarking on her next international adventure: she has been awarded a Fulbright scholarship to return to Senegal in October to study coastal hazards. **M!**

Associate Professor Merrick Haller talks with master's student Annika O'Dea about the interaction of waves and wave energy converters.



The simulated wave shadow cast by a wave energy converter array along the Oregon Coast, just south of Newport.



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