PMEC
Pacific Marine Energy Center

2025 YEAR IN REVIEW

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ABOUT US

PMEC is a consortium of three universities focused on responsibly advancing marine energy by expanding scientific understanding, engaging stakeholders, and educating students. We serve as an objective voice regarding the opportunities, capabilities, and effects of marine energy, including wave, tidal, and riverine resources.

Researchers from the University of Washington, Oregon State University, and University of Alaska Fairbanks work closely with marine energy technology developers, academic and National Laboratory researchers, coastal community members, ocean users, federal and state regulators, and other government officials to address key challenges in the sector and accelerate its emergence.

As a consortium, we unify research & development, testing, and educational programs in marine energy across our three partner universities. Individual projects typically cross-cut these capabilities and often involve collaborative teams drawn from multiple institutions. For example, a graduate student might conduct research towards their degree at one of the affiliated test facilities. Further, our scope includes technology, the environment, and society, with projects often cross-cutting these areas.

LETTER FROM THE DIRECTOR

Dear PMEC colleagues, friends, and partners,

As we move into 2026, I want to take a moment to celebrate what we have accomplished together over the past year. The impact of PMEC's work—on the communities we serve, the students we mentor and graduate, and the agency missions and partners we support— is both meaningful and far-reaching. For communities and utilities seeking to add reliable energy to their mix, PMEC conducted resource assessments to inform their decision-making. For developers, PMEC collaborated on device testing and contributed foundational knowledge in methods and design for turbines and wave energy converters alike. For regulators and communities, PMEC literally put a new lens on our understanding of wildlife interactions with marine energy devices, and for the broader marine energy community, PMEC supported and mentored students in becoming leaders in the field. We serve a vast array of stakeholders, from industries and developers to communities, educators, and the national and international research community. Through these relationships, PMEC remains steadfast in its commitment to deliver the highest quality research and development in the advancement of marine energy.

This 'Year in Review' highlights just a few examples of the many activities underway across our partner institutions at Oregon State University, the University of Washington, and the University of Alaska Fairbanks. Collectively, these efforts reflect PMEC's dedication to advancing renewable power at sea, supporting communities as they participate in the energy transition, and developing the next generation of marine energy technologies and leaders.

In 2025 alone, PMEC-affiliated faculty, staff, and students collaborated with 13 technology developers, three national labs and test sites, eight outside universities, and more than a dozen energy agencies, Tribal governments, municipalities, non-profits, and technology developers around the world. Students and faculty won national and international awards for their work, published over 28 journal articles and 18 conference proceedings, and led or participated in over a dozen community events across the Pacific Northwest and Alaska. These accomplishments are a testament to the expertise, perseverance, and teamwork across our consortium.

This year also brought challenges, and the PMEC community responded—with resilience, generosity, and strong support for one another. The strength of our partnerships and shared purpose has enabled PMEC to continue to grow, support our students and collaborators, and lead within the academic marine energy community.

Looking ahead to 2026, I am excited to build on this momentum as we expand PMEC's global presence and strengthen partnerships in Canada, Europe, and beyond. The success of this past year reflects the skill, dedication and passion of every individual involved.

Thank you for your continued commitment to PMEC and to the communities and mission we serve.

Cheers,
Bryson Robertson, PMEC Director & OSU Professor of Civil and Enviro Engineering

**As of January 2026 Bryson Robertson has taken a new position at the University of Victoria. We thank him for his leadership and service to PMEC!*

NEW ASSOCIATE DIRECTORS

In 2025, PMEC welcomed two new associate directors to the leadership team: Emma Cotter and Owen Williams. Cotter is a PMEC alum and a Research Engineer in the Coastal Sciences Division at Pacific Northwest National Laboratory with a joint appointment in the Department of Mechanical Engineering at the University of Washington. Williams is an Associate Research Professor in the Department of Aeronautics and Astronautics at the University of Washington.

PMEC's outgoing associate directors, Shana Hirsch and Michelle DiBenedetto, made many invaluable contributions to the PMEC community and collaboratively charted our research center through a phase of significant growth.

In these interviews, Cotter and Williams share their history with marine energy and interests as PMEC leaders.

Emma Cotter

What inspired your interests in marine energy?

In my middle school, there was an all-girls robotics program. There were probably 40 students in it, it was a really big group. It was a cool environment at such a young age to be able to explore engineering. While at the moment, I wasn't putting it all together, I think that helped me start thinking about the world in a certain way.

Later, while exploring my options for grad school, I realized that the projects that excited me most were related to the development of environmental sensing systems. I talked with Brian Polagye and ended up working on a project developing an integrated sensor system for environmental monitoring at marine renewable energy sites - the Adaptable Monitoring Package. I didn't know anything about marine energy at the time, but I'm so happy that I ended up in this field.

Now, most of my research relates to environmental monitoring of offshore renewable energy systems. My work focuses on developing the tools and methods to understand how anthropogenic activities in the ocean interact with the environment.

Read more about Emma's work in "Power at Sea: Turbine Lander and the Adaptable Monitoring Package"

What excites you about marine energy right now?

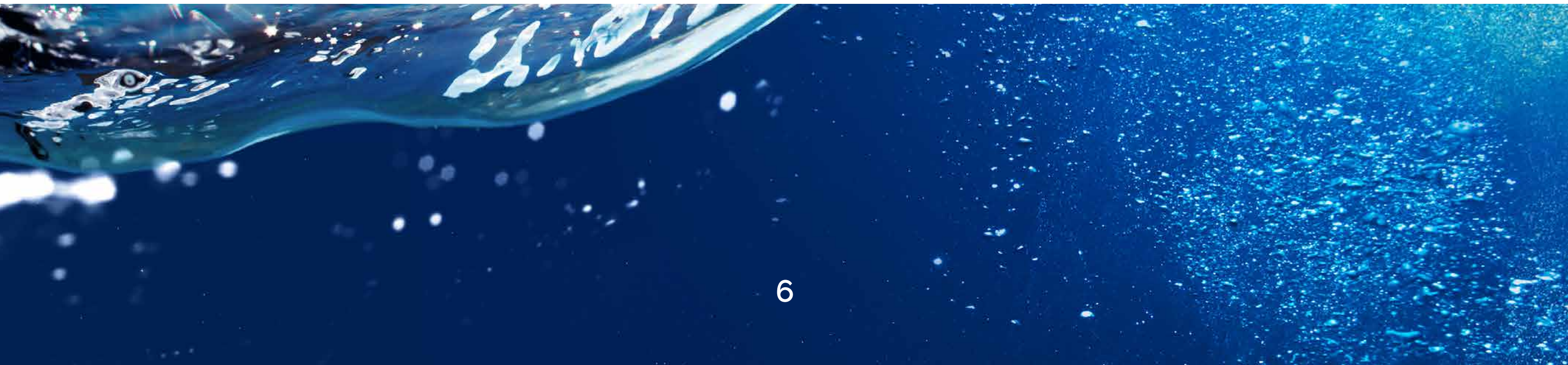
The broad range of research questions and technical expertise that's needed. It's really neat getting to work in a field with so much overlap between social, environmental, and engineering fields.

How did you initially connect with PMEC?

I've been involved with PMEC for more than 10 years now, first as a graduate student from 2014 – 2019, then again when I joined the staff at Pacific Northwest National Laboratory (PNNL) with a joint appointment in the Mechanical Engineering Department at the University of Washington.

What are you hoping to improve or build upon, as an associate director?

I am interested in developing alumni relationships and providing support for students that are interested in careers at the national laboratories working on marine energy or adjacent topics.



Owen Williams

What inspired your interests in marine energy?

My background is in aerodynamics and hydrodynamics. I was always interested in vehicles and things that fly. I also grew up in Ontario, and love being on the water. [This field] helps me blend my interest in being on and around the water with my background in conventional aircraft and vehicles. Renewable energy presents a lot of really big challenges from an aerodynamics perspective: moving, unsteady flows and a lot of unforgiving environments. It's a fun way to bring it all together, and have a positive impact.

What research are you excited about right now?

I'm really excited about the work conducted by my student Ari Athair. His interest has been the shape of the blades we use in [tidal] turbines. Traditionally, because cross-flow turbines rotate, the flow greatly changes direction around the cycle. As a result, everyone thought, 'let's start with a foil that is symmetric, we don't see a reason to do much else,' but our understanding has evolved. We now understand that as the blade goes around a curve, the blade is effectively curved as well, in a virtual sense, and that curvature ties into what the optimal pitch and shape should be. Ari has done experiments looking at how we optimize the shape of these blades to either get higher power or smooth out the loading on the turbine, something which could have structural or power quality benefits.

Read more about Ari's research in "Enhancing Performance: New Tools for Cross Flow Turbine Design"

How did you initially connect with PMEC?

I've been involved with a lot of different programs and pieces of programs with PMEC researchers at UW. Our recent work exploring the impact of turbulence and eddies on turbine power production brings me back into my traditional background in aerodynamics.

What are you hoping to improve or build upon, as an associate director?

I want to help bring people together to cross-pollinate ideas between different institutions and labs and advocate for marine energy from lab to production. The more we can foster connections between the universities and with industry, the better.

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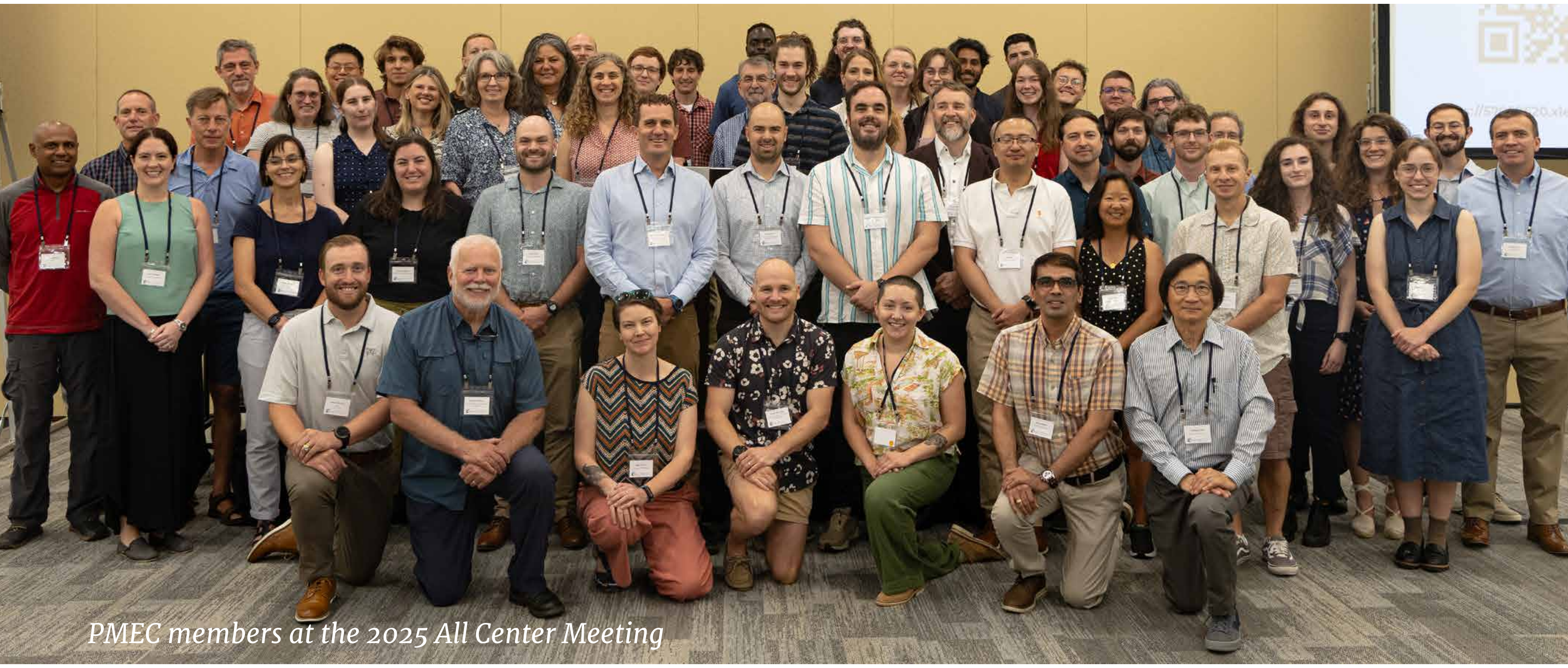
**In early 2026, WPTO was renamed the Hydropower and Hydrokinetics Office (H2O).*



PMEC members at the 2025 All Center Meeting

RESEARCH HIGHLIGHTS

PMEC's impact extends through all aspects of marine energy research and development, from initial concept and modeling studies to deployments and field testing. In these research highlights, we showcase a selection of research outcomes in three areas: 1) Advancing marine energy to provide power at sea, 2) Powering communities through collaborative research, field testing, and social science, and 3) Fundamental research that enhances the design, performance, and efficiency of marine energy converters.

POWER AT SEA

Marine energy holds vast potential to enhance ocean observing, sensing, maritime defense, and the blue economy at large. The US West Coast, particularly the Pacific Northwest, is one of the greatest wave power regions on the planet. In the calmer seas of summer months, wave energy off the Oregon Coast averages 20 kilowatts per meter (kW/m) of shoreline. This ramps up to 70 - 80 kW/m in stormier winter months. Similarly, tidal currents through the island waterways of Alaska and the Pacific Northwest produce some of the largest sources of tidal power on Earth. Arrays of tidal turbines or wave energy converters could produce grid-scale power, while a single wave energy converter or compact turbine could provide more modest amounts of power for remote offshore operations such as aquaculture, ocean monitoring systems and AUV recharging for research and offshore energy applications. And since wave and tidal energy is more predictable and less variable than solar and wind power, it has the potential to be used to create a more stable, continuous, and reliable power supply.

The path toward harnessing ocean energy has many obstacles. Seawater is corrosive and everything from algae to barnacles to starfish and seaweed wants to stick to and grow on the submerged surfaces. The energy that makes sites suitable for extracting power places tremendous forces on objects deployed in the field. And, of course, operations at sea are complex and costly. To overcome these hurdles, multidisciplinary scientific and engineering breakthroughs must happen simultaneously.

For over a decade, the Pacific Marine Energy Center has been aligning a constellation of testing facilities, multidisciplinary expertise, and the human relationships needed to advance these ocean technologies of the future. The stories in this section highlight results from a sampling of the 2025 research projects that are advancing power at sea.

TURBINE LANDER AND THE ADAPTABLE MONITORING PACKAGE

In 2023, a multi-institutional team led by Chris Bassett and other PMEC researchers at University of Washington's Applied Physics Laboratory deployed and operated a first generation prototype of a compact marine current turbine in Sequim Bay, Washington (USA) for over five months. This had never been done before in the Pacific Northwest. The system, referred to as the Turbine Lander, was the product of a laboratory-to-field effort to develop a system that seeks to enable enhanced ocean sensing or vehicle recharge in remote, energetic settings with no existing power infrastructure. Additionally, it was designed to generate not only power, but also high-quality and well-resolved data streams to assess its performance.

In 2025, the team published an assessment of the design, operation, and post-recovery engineering. For the initial deployment, survival of the turbine was prioritized over efficiency, and commercial off-the-shelf components were used to enable high-quality data acquisition. While components performed well, the added features associated with off-the-shelf equipment used on factory floors was not well-aligned with the needs of long-term, autonomous deployments. Building on this initial deployment and lessons learned, the team fabricated and tested a second generation system. In this iteration, the team prioritized efficiency, power production, and the ability to integrate with energy storage to advance the concept toward autonomy. These efforts resulted in significant performance improvements. For example, in addition to producing power at lower inflow speeds the second generation system consumes less power during operations. The new design can produce more than 2 kW when the current flows at 2.5 m/s, over 500 W more than the initial design. These improvements were achieved not by a single, significant modification to the system, but by a large number of incremental changes. Together they provide a pathway for achieving performance improvements in other small-scale systems where differences as small as a few tens of watts determine a project's feasibility.

> *"One of the questions that we often ask is, are we going to introduce potentially new problems as we seek to develop this new technology? We would like to avoid doing so, and one way to do so is to think about, from a high-level perspective, what are all of the different ways that the deployment of this new technology could have environmental impacts, to measure those upfront as the technologies are developing and try to get out ahead of that, potentially modifying the technologies or try to address the topics early rather than taking a reactionary approach down the road." — Chris Bassett*

Given the complex factors that go into turbine design, a key outcome from this process was learning that system optimization requires a cooperative design approach. In practice, this means active design participation by those familiar with all aspects of the system (i.e., hydrodynamics, manufacturing, mechanical, electrical, software, and operation), and basing decisions on detailed knowledge of how individual choices about specific subsystems impact others.

The first generation Turbine Lander deployment also provided a unique opportunity to study animal interactions with a tidal turbine. To do this, the team, co-led by Emma Cotter, integrated an environmental monitoring system called the Adaptable Monitoring Package into the platform, which enables many sensors to be operated as a single unit. This allows for sensors to be operated without interfering with each other and for real-time data processing to be used to make decisions about archiving data (a significant advantage when events of interest are relatively rare). PMEC researchers at UW, in coordination with MarineSitu, have been developing tools to conduct environmental monitoring in these environments for years, and this was their first opportunity to put them to the test on a tidal turbine.

After the deployment, the team analyzed hundreds of hours of camera footage to identify animal interactions with the turbine. Results from this work are published in PLoS ONE (Cotter et. al, 2026), and were presented at the 2025 European Wave and Tidal Energy Conference. The team has also started planning an improved environmental monitoring campaign based on lessons learned for the next deployment of the Turbine Lander. "We are looking forward to a new opportunity to repeat the work and obtain a data set that moves beyond capturing events and seeks to quantify rates of avoidance and evasion to support assessments of collision risk," says project co-lead Chris Bassett.

"This rich dataset represents first-of-its-kind optical camera imagery showing fish, bird, and marine mammal interactions with an operational tidal turbine in North America, and we anticipate that this information will be valuable to regulators faced with making decisions about tidal energy permitting and researchers planning future studies." — Emma Cotter

Note: this project has been highlighted in multiple media outlets:

1. Critics feared tidal turbines are 'underwater blenders' but new footage proves marine life knows how to dodge them. *ZME Science.*

2. Watch: wildlife interact with underwater turbines. *Wildlife*.org.

3. Photos: 1,044 marine animal observations analyzed for tidal turbine collision risks. *Interesting Engineering.*

4. Underwater cameras could help unlock america's tidal energy industry. *Inside Climate News.*

5. Spy camera dropped into sea off Washington coast and left there for more than 100 days. This is why. *BBC Wildlife Magazine.*

6. Understanding environmental effects of small scale tidal turbines: Insights from Sequim Bay. *Tethys Stories.*

7. Marine wildlife rarely interact with tidal turbines, and usually avoid collisions when they do, observations show. *Phys*.org.

8. Experts left a camera underwater in Washington fro 100+ days– the result is completely unexpected. *Green Matters.*

Number of students contributing to this project: 3
Collaborators: Pacific Northwest National Laboratory, MarineSitu
Project Supporters: U.S. Dept. of Energy WPTO, NAVFAC EXWC, and TEAMER

2025 Notable Recognitions of PMEC Scholars

- Shima Abadi (UW Oceanography) twice recognized for her research in Ocean Acoustics:
    - Medwin Prize in Acoustical Oceanography, Acoustical Society of America.
    - Wood Medal and Prize, Institute of Acoustics, UK

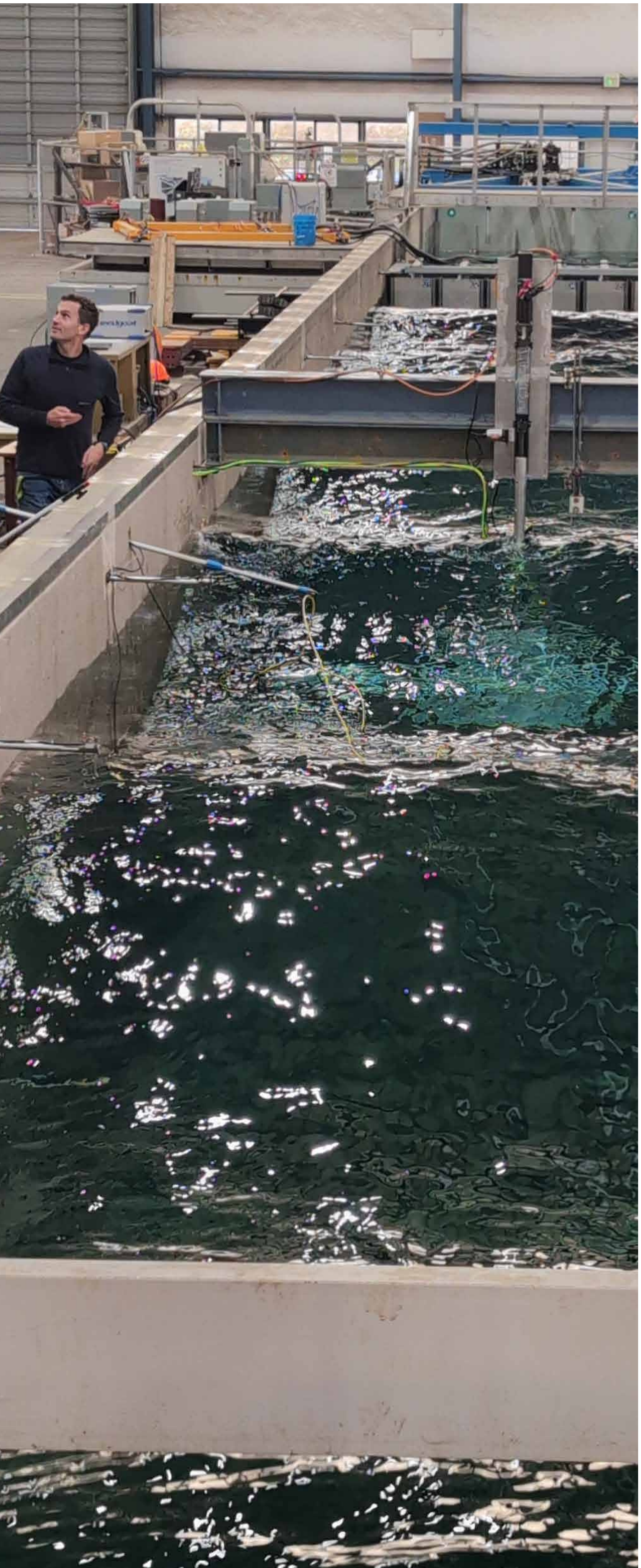
- Chris Bassett (UW Applied Physics Laboratory) received the 1906 Award from the International Electrotechnical Commission (IEC) for contributions to standards associated with noise measurements for marine energy converters.

- Graduate students Gavin Andres and Rakesh Vivekenandan, and Tanvir Shifat (OSU) won the Best Student Poster Award at the University Marine Energy Conference (UMERC)/Ocean Renewable Energy Conference (OREC).

- The Marine Renewable Energy Club (OSU) won the Best Build and Test Award at the national Marine Energy Collegiate Competition.

- Brian Polagye (UW Engineering) and Chris Bassett (UW Applied Physics Laboratory) featured on the Across Acoustics Podcast: The Acoustic Impacts of Marine Energy Converters.

WAVE POWERED AUTONOMOUS UNDERWATER VEHICLES



The Hinsdale Wave Research Laboratory at Oregon State University, a massive 7,500 square meter building, hosts one of the largest wave flumes in North America. It's a 104 meter long, 4.7 m deep channel designed for offshore wave and tsunami research.

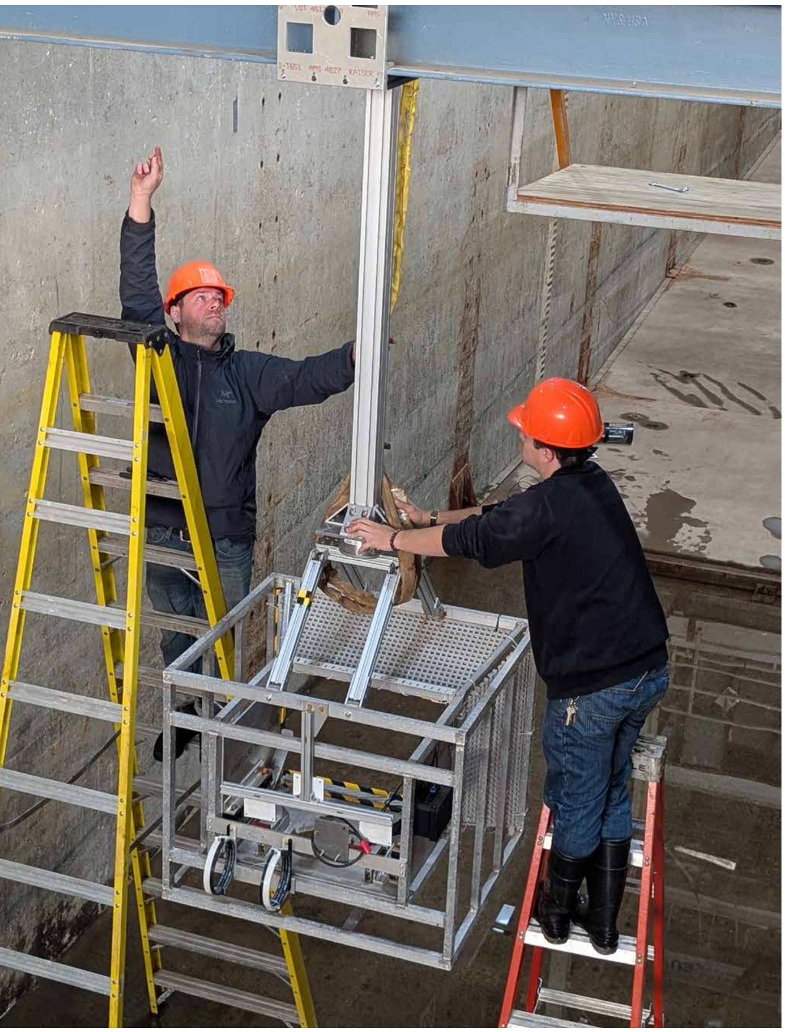
Inside the lab on a crisp October afternoon, doctoral student Rakesh Vivekanandan watched on a monitor as an underwater robot, which he meticulously programmed, successfully navigated through 50 centimeter high waves into a submerged docking station. He's part of a large and diverse team led by OSU professor and roboticist Geoff Hollinger. In 2025, the team completed the final milestone in a four year project coupling autonomous underwater vehicle (AUV) docking with a wave energy converter (WEC).

Their goal: to couple and advance WEC and AUV technologies so they're ready to test together in the open ocean on the path towards commercialization. Testing in the Hinsdale lab is a necessary stepping stone because it can mimic real world open ocean waves. Open ocean testing is expensive and fraught with logistical and environmental challenges, so researchers test as much as possible in the laboratory first, where experiments can be run at a fraction of the cost, before taking things to sea.

The project's long-term vision is for underwater vehicles to navigate autonomously to a wireless recharging dock that is connected to the bottom of a WEC, which converts the abundant kinetic energy from waves into electricity. But for lab testing, the wave flume wasn't deep enough for both a WEC and the dock. To work around this and make lab testing possible, the team mounted a dock to an I-beam with actuators that moved it as if it were connected to a WEC bobbing around on the surface of the ocean. For this, they built a numerical model to simulate how the WEC would move the dock, in real time.

The size of the AUV created additional challenges for the lab tests. Typically in lab testing, scale model devices are used and everything is done in miniature, but the AUV couldn't be scaled down, which meant that the docking station also couldn't be scaled down. That meant that tests needed full-scale ocean waves. Though Hinsdale's wave flume is one of the largest testing facilities of its kind in North America, even this lab cannot exactly mimic the powerful waves off the Oregon coast. In order to simulate realistic ocean waves, the team had to get tricky.

Ocean waves, explained Bryson Robertson (a project co-lead), generate two forces relevant to AUV docking. Water particle acceleration governs mass and inertial forces, and wave velocity governs drag forces, so Junhui Lou, one of the OSU hydrodynamicists on the team, deconstructed full scale ocean waves into the two component forces that the AUV would experience in the ocean. One set of laboratory waves mimicked the acceleration of open ocean waves, and another set of waves mimicked the velocity.



"Prior work has been purely theoretical. Success in the lab means we are ready to do field ocean demonstrations." — Bryson Robertson

"We were surprised by how well the systems fit together…the wireless charging, the autonomous systems, the marine energy devices, all of these components are at the cutting edge and we are putting them together and exploring this new way of interacting with the ocean," — Geoff Hollinger

"The AUV performed very well, it docks without any problem. We ended up using the largest wave heights we can create in the wave flume. " — Junhui Lou

In the first year, the robotic challenge was to determine how to get the robot's position while it is bobbing around so that it can navigate towards a moving target. Ocean water is extremely turbulent, and visibility is often poor, so they experimented with a variety of sensors – many of which were custom designed by engineers on the team – to help the robot determine its location in space, including a camera, a sonar, a pressure sensor, an inertial measurement unit (IMU), and a Dopper velocity log.

Vivekanandan, the PhD student who took on this challenge, chose this project for his thesis because he saw the potential for positive societal impact. After initial testing, he learned that the computations used to generate the control inputs for moving the robot were too slow, and that making this processing significantly more efficient was necessary for responsive motion. And to ensure that the AUV can charge wirelessly from any WEC, not just the one they are testing in Hinsdale, Vivekanandan ran his models on a device at UW's Applied Physics Laboratory — a benefit of having a large, multi-institutional team. His navigation method incorporates active perception into a predictive control framework so that the AUV can estimate how the dock is moving upon approach.

Getting the vehicle to navigate into the docking station is one part of this project, but once it's there another component is underwater wireless charging. That piece was completed by engineers Curtis Rusch (PMEC graduate) and Dana Manalang from UW's Applied Physics Lab.

The initial docking attempts were unsuccessful, and that showed the team what was needed next: collision detection. "Gavin Andres developed code that fused together data from multiple sensors to create a motion panning algorithm," says Vivekanandan, who mentored Andres, a masters student, on the project.

After each year of testing in the lab they made iterative improvements, and challenged the AUV to dock under bigger and more powerful waves. Each year, they succeeded.

In October 2025, the AUV docked under the most challenging lab conditions the team could generate. Now the team is wrapping up this project, and they've met their goals. The next step is to test this in the open ocean, and team members from the Hawaii Marine Energy Center have been on the project to ensure readiness for testing in their Wave Energy Test Site (WETS) in Kaneohe Bay, HI.

Number of students contributing to this project: 4
Collaborators: University of Hawaii at Manoa, UW Applied Physics Lab, Marine Energy Industry
Funding: U.S. Dept. of Energy WPTO



MARINE GROWTH AND BIOFOULING ON MARINE ENERGY DEVICES

When wave energy devices and their associated moorings are in the water, they are colonized by barnacles, mussels, seaweed, and other organisms. This is known as biofouling. Because biofouling changes the surface roughness of a device, it can reduce device performance. Biofouling removal adds to project costs, and discarded biofouling settles to the seafloor. As that organic matter decomposes, it has the potential to affect local oxygen levels leading to ecological impacts. Further, mobile animals like fish, octopus, or crabs may be attracted to the buoys and the life growing on them. Collectively, this colonization and attraction can affect how marine organisms are distributed in natural habitats – larvae or adults may use these offshore structures as stepping stones between rocky reefs and previously isolated habitats. For these reasons, a better understanding of biofouling can inform project planning and environmental effects of devices on local habitats.

In 2024 - 2025, Sarah Henkel, a professor of Integrative Biology at OSU, conducted field work with graduate student MJ Strike, to build a more detailed understanding of biofouling off the central Oregon coast. They quantified biological growth on floating structures of different materials and coatings as well as various anchor components over multiple field deployments at the PacWave test sites and the Ocean Observing Initiative buoys.

Grids were placed on various components from each buoy/anchor system and photographed. Then, they scraped off the material and brought it to the lab to measure biomass and identify the species.

They found more biomass and greater diversity on buoys from shallower/closer-to shore deployment compared to deeper/further offshore deployment sites. They also found that species preferred complex surfaces like mesh, over smooth surfaces on individual buoys, and the types of species growing on the buoy components varied with the depth in the water column of the structure.

In 2026, data analysis will include investigating seasonal variability and potentially correlating the results with oceanographic variables.

Number of students contributing to this project: 4

Collaborators: PacWave, Ocean Observatories Initiative

Funding: U.S. Dept. of Energy WPTO

Pacific Marine Energy Center and PacWave

The Pacific Marine Energy Center, formerly the Northwest National Marine Renewable Energy Center (NNMREC), was established by the US Department of Energy's Water Power Technologies Office (WPTO), with the mission to facilitate the commercialization of marine energy technologies, support regulatory and policy development, and address key scientific knowledge gaps, all while fostering student training and development.

By 2015, as NNMREC-led efforts to develop a grid-connected wave energy test site off the Oregon coast became more concrete, it was determined that NNMREC's mission should be divided between two distinct but complementary entities – PMEC and PacWave.

PacWave's mission is to establish and operate the world's leading wave energy testing facility. As a fully pre-permitted, grid-connected site, PacWave is responsible for providing comprehensive support for testing, research & development, demonstrations, and deployments for wave energy converters (WECs) and other innovative marine technologies.

In 2025, PacWave reached an historic Power Purchase Agreement (PPA) with the Bonneville Power Administration (BPA). BPA provides about one-third of the electric power generated in the Northwest of the US, primarily from reliable, dispatchable, and flexible hydroelectric resources. The PacWave PPA with BPA is the first wave energy PPA in the USA, and allows PacWave to deliver power to major utilities across the Northwest USA. The power will be harvested by wave energy converters in operation at the PacWave site off Newport, Oregon, and this PPA provides a fundamental step in signalling commercial demand for wave energy technology. This agreement can serve as a model for other commercial projects, and advances the sector toward 'bankability'.

PacWave
TESTING WAVE ENERGY FOR THE FUTURE

In the media:

Offshore Energy Biz | NewsData | BizJournals | Seattle Times

POWERING COMMUNITIES

In Alaska, multiple remote indigenous communities are seeking to augment or replace their diesel power with river current turbines that leverage the steady and abundant power in the rivers that support their communities. In the lower 48, PMEC researchers have developed understanding of coastal community perspectives on both the impacts and benefits of energy development. The stories in this section represent a subset of the 2025 research projects addressing power for remote communities and community perceptions of marine energy.

Photo Credit: Igiugig Village Council

Community Voices: Igiugig's River Turbine

Editor's Note: AlexAnna Salmon is of Yup'ik and Aleut descent and serves as president of Igiugig Village Council, the governing body for Igiugig, a remote community in southwestern Alaska with no road access. Below is an excerpt from forthcoming University of Alaska Press publication Alaska's Energy Innovators, that shares the most remarkable story of a tiny village willing to experiment with river hydrokinetic technology placed in a stream which has provided the livelihood of Native peoples for millennia. This excerpt was previously published by the Alaska Center for Energy and Power (ACEP).

By AlexAnna Salmon and the Native Village of Igiugig April 25, 2025

In Igiugig, we approach sustainable energy through the frame of tribal sovereignty and the Indigenous values that guide our ways of life. The word Igiugig means "like a throat that swallows water" in the Yup'ik language. Our village is located where Lake Iliamna is swallowed by the Kvichak River. We have lived in this area for over 8,000 years. For most of our history, we moved around seasonally following the movement of the foods we depended upon and still depend upon. Our village settled in one place to open a school to keep our youth at home. The Alaska Native Claims Settlement Act of 1971 (ANCSA) followed, cementing our place as we became a year-round community.

Like most Alaska villages, our initial experience with electrification was through diesel. It improves our quality of life in many ways, but it has heavy costs. It is dirty, it's noisy, spills are inevitable, and in recent years we have come to understand the broader impacts to climate. And we are on the frontlines of those impacts.

Our fuel used to be delivered by barge when the water was highest, typically in the fall. But with climate change, water levels became erratic. That made our energy system even more precarious, because we had to shift to delivery by air in small batches. In summer 2024, our fuel supplier had a fatal crash outside of Fairbanks and our community had to scramble to find a replacement provider. We also watched our bulk fuel farm of 114,000 gallons nearly collapse into the river as a result of climate-driven erosion. We did not want to be dependent on outside sources for our energy anymore.

Visioning a sustainable energy future

It was in this context that our village started meeting around the year 2000 to do comprehensive community planning. We are a traditional community, gathering the way we have since time immemorial to talk about current challenges and putting forth solutions rooted in our indigenuity – our Indigenous ingenuity. We make decisions based on 100 percent consensus and all age groups are included.

We decided as a community to diversify our energy system and applied to the state's newly created Renewable Energy Fund in 2007. We received a grant in the very first round of awards of $750,000 to develop hydrokinetic power, a renewable energy source generated by the movement of a body of water – in our case, the Upper Kvichak River.

We realized we had an opportunity to use our permits (whose cost was covered by the grant) to test new types of hydrokinetic devices. Igiugig is a good test site because conditions are so difficult out here. If we can prove a technology or process in Igiugig, it can be done anywhere in the world.

In 2012, four companies came out to Igiugig to explain their technologies. We narrowed the pool to two companies. The first one didn't listen to any local advice, and grossly underestimated the power of our river. The device broke its mooring lines upon deployment – not once, but three times! They flipped the skiff they were using to install the device. They left their mess behind and we never heard from them again.

The other company, Ocean Renewable Power Company (ORPC) honored our Indigenous knowledge and expertise. From the type of anchor used to the method of deploying their device, they learned from and leaned on the local community and knowledge. Over time, our relationship and our trust grew.

We partnered with ORPC to apply for two federal grants and have been able to test and improve the design of their device (called RivGen) over the past decade. Because of the life cycle of salmon, we had to ensure our hydrokinetic device did not harm two sockeye salmon migrations each year (outmigrating smolt, and returning adults). We relied on our Indigenous knowledge to inform key design decisions to protect the salmon. The RivGen turbine has pontoons and mounts on the river itself. The pontoons are filled with air so they float but can also be filled with water so they sink to the bottom, held in place with an anchor. The turbines can be turned off or removed from the river when needed.

Sovereignty sets the stage for community energy goals

For us, it is about more than energy. Energy is the mode we used to build our capacity. Igiugig has used a tribal sovereignty approach to our energy transition so our energy efforts strengthen our nation, governance, and wellbeing. We are not the problem to be solved. We are the answer.

Photo Credit: Igiugig Village Council

PMEC researchers have been honored to support this project through multiple environmental monitoring, resource assessment, and performance assessment studies.

PMEC publications, reports and datasets associated with Igiugig's RivGen™ Turbine:

Cotter, E.; Haxel, J.; McVey, J. (2025). Passive Acoustic Monitoring of a Riverine Turbine with Stationary Hydrophones (Report No. PNNL-38798). Report by Pacific Northwest National Laboratory (PNNL). Report for US Department of Energy (DOE). https://doi.org/10.2172/3008470

Polagye, B., Bassett, C., Jones, L., Calandra, G., & Crisp, C. (2025). *TEAMER: Passive Acoustic Measurements around ORPC Turbines in Millinocket, ME and Igiugig, AK*. [Data set]. Marine and Hydrokinetic Data Repository. University of Washington. https://mhkdr.openei.org/submissions/666

Polagye, B., Bassett, C., Jones, L., Calandra, G., & Crisp, C. (2025). *TEAMER: Acoustic Characterization of ORPC Device Sound Signatures - Public Report and Data*. [Data set]. Marine and Hydrokinetic Data Repository. University of Washington. https://mhkdr.openei.org/submissions/678

Courtney, M.; Flanigan, A.; Hostetter, M.; Seitz, A. (2022). Characterizing Sockeye Salmon Smolt Interactions with a Hydrokinetic Turbine in the Kvichak River, Alaska. North American Journal of Fisheries Management, 42(4), 1054–1065. https://doi.org/10.1002/nafm.10806

Joslin, J., Riel, C., Gibbs, P., & Murphy, P. (2021). TEAMER: *A Tow Body Optical Camera System*. [Data set]. Marine and Hydrokinetic Data Repository. University of Washington. https://doi.org/10.15473/2481238

Thomson, J., & Guerra, M. (2018). *ORPC RivGen Hydrokinetic Turbine Wake Characterization.* [Data set]. Marine and Hydrokinetic Data Repository. University of Washington. https://doi.org/10.15473/1432537

Kasper, J., Duvoy, P., Konefal, N., Cannavo, A., Brown, E., Bond, B., & Cicilio, P. (2017). *Next Generation RivGen Power System: Kvichak River, AK Overwinter Ice Study.* [Data set]. Marine and Hydrokinetic Data Repository. Igiugig Village Council. https://doi.org/10.15473/1492960

Forbush, D., Polagye, B., Thomson, J., Kilcher, L., Donegan, J., MacEntee, J., (2016). *Performance Characterization of a cross-flow hydrokinetic turbine in sheared flow.* International Journal of Marine Energy. https://doi.org/10.1016/j.ijome.2016.06.001

Polagye, B. (2016). *RivGen Acoustic Measurements, Igiugig, AK*. [Data set]. Marine and Hydrokinetic Data Repository. University of Washington. https://doi.org/10.15473/1419015

Thomson, J. (2015). *RivGen Wake Data, Igiugig, AK.* [Data set]. Marine and Hydrokinetic Data Repository. Northwest National Marine Renewable Energy Center. https://doi.org/10.15473/1420173

Thomson, J., Kilcher, L., & Polagye, B. (2014). *RivGen Current Flow Measurements, Igiugig, AK.* [Data set]. Marine and Hydrokinetic Data Repository. Ocean Renewable Power Company. https://doi.org/10.15473/1418350

Community Events Across the Pacific Northwest and Alaska

PMEC hosted a meeting with Congresswoman Suzane Bonamici at Oregon State University, together with industry and non-profit leaders.

Chris Bassett presenting research on environmental monitoring for One Ocean Week, Seattle

Brian Polagye sharing acoustic monitoring devices in a laboratory demonstration for One Ocean Week, Seattle

Researchers from PMEC's three universities gather for the All-Center Meeting to discuss visions and strategic goals.

David Okushemiya, PhD student at Oregon State University, presents his research for Congresswoman Bonamici.

PMEC's All Center Meeting Reception fell on the birthday of board member Grace Chang.

Pedro Lomonaco, Director of the O.H. Hinsdale Wave Research Laboratory, gives a lab tour as part of the UMERC + OREC conference.

PMEC scholars presented at the "State of the Coast," sponsored by Oregon Sea Grant.

LISTENING IN THE RIVER: NEW DAISY MEASUREMENTS

In 2024, researchers from the University of Washington had an opportunity to deploy drifting sensors (called DAISYs) to measure radiated noise from the RivGen™ turbine in Igiugig, AK that was co-developed by the village of Igiugig and Ocean Renewable Power Company. In the same season, a team of researchers from Pacific Northwest National Laboratory (PNNL) deployed stationary sensors. From these stationary measurements, they compared noise levels in the river when the turbine was operating to when it was shut down. As expected, it modestly increased low frequency noise (sounds below a few kilohertz), but they also found something surprising: when the turbine was operating, high frequency sounds got *quieter*.

The drifting measurements that the UW team analyzed this year helped explain this surprising observation. Their measurements confirmed that the operation of the turbine does, indeed, increase noise levels around the turbine at frequencies that may be perceived by fish (< 1 kHz). This noise gets quieter as one moves away from the turbine, but at higher frequencies, that pattern breaks down. There is a clear reduction in noise downstream of the turbine (where the PNNL sensors were located), while other parts of the river get *louder*.

In the natural river, the primary cause of these high-frequency sounds is from rocks and finer-grained sediments clinking together under the force of the moving water. In areas where the water is moving faster, the noise from the sand and pebbles jostling against each other is louder. This is called *sediment-generated noise*.

The turbine alters the movement of water in the river: just downstream of the turbine where the river's energy has been converted to electricity, the water flows more slowly, but around the sides of the turbine the flow speeds up a bit. Picture the flow around a big boulder in a fast-moving stream (see image below), where you would expect to see water flowing quickly around the sides of the boulder and a pool of calm water immediately downstream of the boulder.

When the turbine is operating, it creates a downstream wake where the water moves more slowly, and thus less sediment is moving around. Conversely, where water is redirected around the turbine, water velocity increases and so does sediment transport noise.

So, when considering the effects that a turbine can have on a river soundscape, there are direct effects, like noise from the rotating equipment, and indirect effects, like changes to sediment transport. In this particular case, the changes to the high-frequency soundscape are academically interesting, but don't matter to fish. The UW and PNNL teams are working to publish and present these findings in 2026.

Number of students contributing to this project: 1
Collaborators: Pacific Northwest National Laboratory
Project Supporters: Testing supported by TEAMER, DAISY development supported by U.S. Dept. of Energy WPTO

THE TANANA RIVER TEST SITE GETS AN UPGRADE

PMEC's research team at the Alaska Center for Energy and Power (ACEP) at the University of Alaska, Fairbanks operates a riverine test facility about 60 miles southwest of Fairbanks in Nenana. The Tanana River Test Site (TRTS) is one of only a few facilities worldwide that offer in-river testing of kilowatt scale river current turbines. Its proximity to Fairbanks and position on a major Alaskan river makes the facility an ideal place to test and prepare new technologies prior to deployment in a community.

Until this past summer, staffing availability limited the number of hours available for testing. Previously, staff would need to be on site for the extent of testing, and not just one person but the whole team including the site manager and any clients who often had to fly into Fairbanks. The test device could not be left in the water overnight, so each day had significant set up and take-down time.

In summer 2025, the research team performed major upgrades to automate the test site so that staff can perform long-duration testing of new technologies without being physically on site 24/7.

One of the upgrades was improved resilience against debris: springtime in Alaska means glacial runoff. Rivers run high and sweep all the dead trees and branches from the river edge into their flow. And later in the year, heavy late-summer rains can produce flooding conditions that bring another surge of debris into the rivers. During flooding events, it's not uncommon for large trees to flow by every minute.

Testing equipment must not only withstand these impacts, but must also operate under a wide temperature range, from summertime heatwaves to fall freezes. To this end, they replaced the old 500-gallon buoy that was anchoring the barge with a more rugged design with more crossbraces to protect against collisions with giant trees floating down the river. They also deployed a new debris diverter with a solar-powered buoyancy control system designed by student intern Lucian Rodriguez.

The second step was to have a reliable and autonomous electric power system on the research barge deck to power the auxiliary equipment needed to support testing, including the machinery for deployment and retrieval of the turbine, environmental and electrical data-acquisition systems and communications systems. To achieve autonomy, the team set up a mini grid with a battery-inverter system, solar panels and a gasoline generator. The auto-start generator automatically recharges the batteries as a backup for the solar panels installed on the barge gantry. This system is designed to operate for weeks without any servicing, and can be remotely monitored.

The mini grid was powered on in early July and operated with minimal disruptions until the barge was removed from the river in October.

With the installation of surveillance cameras and high-speed internet, checking conditions at the site became as simple as logging onto a remote portal from a team member's home or office.

"Having alert notifications on our phone gave us the peace of mind to leave a turbine in the water overnight and on weekends," said Luke Woodhouse, a research professional with the marine energy team.

These upgrades ultimately supported an 11-day remotely monitored river current turbine test in August, described in our next research highlight.

Number of students contributing to this project: 1
Funding: U.S. Department of Energy WPTO

TESTING THE BLADERUNNER RIVER TURBINE FOR THE NAPAIMUTE COMMUNITY

PMEC's marine energy team at the Alaska Center for Energy and Power at the University of Alaska Fairbanks is co-leading a pilot deployment in Napaimute, Alaska on the Kuskokwim River. BladeRunner Energy, founded by PMEC alum Moriel Arango, is developing community-scale river current turbines to bring clean and affordable renewable energy to Napaimute and other communities.

This past summer, ahead of a planned 2026 pilot deployment in Napaimute, the PMEC team and BladeRunner Energy completed their most extensive field testing season yet at the Tanana River Test Site (TRTS). Two research projects teamed up for this effort; the MicroC3 grid controller developed by North Carolina State University (NCSU) was integrated with BladeRunner's river current turbine. Both technologies were developed with funding from ARPA-E.

Months of collaboration to connect and integrate subsystems resulted in two week-long "shakedown" tests at the test site in June and July. During these test campaigns the team demonstrated a fully integrated system that incorporated the latest iteration of BladeRunner's tethered turbine technology, NCSU's power controller, and PMEC's data monitoring systems. The goal was to bridge the gap between the power output from the generator and the power needed for a community scale grid.

During the field operation, the team fine-tuned control systems for rotor depth and generator speed setpoints and brought realtime video and data streaming from the test site online.

In August, following upgrades to the TRTS barge, the BladeRunner turbine was deployed for the test site's first ever uncrewed long duration test. For eleven days, the team monitored the system remotely via cameras and data streams. Utilizing MicroC3 and BladeRunner's control system, researchers collected data on system performance across a range of operating conditions. The testing ended when heavy summer rains raised the water height in the river by three feet over Labor Day weekend, picking up large trees and other debris that damaged the system. The outcomes of this test will inform future design improvements for debris mitigation and move the system closer to commercial readiness.

In parallel with these field tests, site preparations were made in Napaimute, Alaska to prepare for a pilot deployment of the same integrated river current energy system in the summer of 2026. These unstaffed tests are the stepping stone toward deployment on the Kuskokwim River to serve the Napaimute Community.

Number of students contributing to this project: 5
Collaborators: BladeRunner Energy, North Carolina State University, Native Village of Napaimute
Funding: U.S. Dept. of Energy ARPA-E

MEASURING UNDER-ICE FLOW FOR THE GALENA COMMUNITY

In late February 2025, Ben Loeffler and Luke Woodhouse of PMEC's marine energy team at the Alaska Center for Energy and Power went to Galena, a rural community of around 500 people on the north bank of the Yukon River, to measure how fast water runs under the ice-covered river.

Very little research has been done on this subject and almost no data is available on the speed of the river flow beneath the ice. Field measurements will help the team assess the feasibility of under-ice power generation and gauge their current and future projects.

In summer, river flow measurements can be as simple as towing a measuring device, called an ADCP, behind a motorboat and taking continuous measurements. An ADCP, short for an acoustic Doppler current profiler, is a device that uses sound waves to measure the speed and direction of currents throughout the water column.

Taking measurements in winter is an entirely different story. Interior Alaskan rivers typically freeze over by late October to November, after which the river width has to be divided into a series of equally spaced points for measurements, where holes are drilled in the ice and an ADCP is lowered into the flow beneath.

Two different locations were identified with input from community members as their areas of interest.

With the help of Galena residents Nolan Aloysius and Tig Strassburg, the team took measurements. Pushing a sled with a mounted ADCP along the path, they used a 10-inch ice auger to drill holes in a straight transect — a straight line across the river — at intervals of approximately 25 yards.

Each transect gave the team many challenges, from damaging the auger blades with silt and rock-laden ice to the accumulation of ice on the ADCP, limiting the depth they could record.

Their measurements ultimately found that river velocities were a quarter to a third of summertime velocities. Further investigation revealed dramatically lessened turbidity — the water was clearer — and a potential lack of debris after the rivers freeze over.

This field work provided an important glimpse into the winter time river current resource available to far-northern communities and the unique challenges that were encountered will help the team prepare for future operations. Next steps include a modeling effort that will expand on existing hydrodynamic tools to better understand under-ice flows and ultimately inform future field measurements for model validation and potential locating of river current devices.

Funding: Alaska Center for Energy and Power (ACEP)

In 2025 PMEC published over 28 journal articles and 18 conference proceedings

COMMUNITY BENEFITS AND ENERGY DEVELOPMENT

How do rural communities perceive the impacts and benefits of energy development? What are the local needs, expectations, and preferences? These were the questions addressed by a multi-institution team of social scientists led by OSU professors Hilary Boudet and Shawn Hazboun. Their research explored community perceptions around existing offshore wind development and has relevance for all forms of energy and industrial development, including hydropower, geothermal, transmission/pipeline construction, and data centers.

The project team conducted interviews of 101 individuals from communities where there is existing offshore wind development or in communities where offshore wind has been proposed. This included communities in Washington, Oregon, California, and Maine.

Additionally, the team administered in-person quantitative surveys of five different prospective offshore wind coastal communities, with representation from both the East and West Coast.
The team also completed an analysis of existing community benefit arrangements (CBAs).

They found that interviewees frequently cited more concerns about potential negative impacts of offshore wind than potential benefits. They also consistently expressed concerns about lacking the capacity, resources, and expertise needed to participate effectively in the community benefits process. There was also a lot of uncertainty, due to both insufficient and excessive—and often conflicting—information. There were mixed and varied understandings of what CBAs are, who should be involved in developing them, and what priorities they should address.

Preliminary findings from interviews in communities with existing offshore wind and also with developers emphasize the mismatched expectations between community members, leaders, and developers surrounding local benefit agreements, as well as the critical role played by non-profit organizations in enhancing transparency, ensuring representation, and providing technical and legal support to communities experiencing energy development.

Note: The grant funding for this project was terminated, which limits the ability to complete the research and share findings with affected communities, and impacts the emerging scholars whose work was supported by this grant.

> **Number of students contributing to this project: 12**
> **Collaborators: Cal Poly Humboldt, University of Delaware, University of Maine, Schatz Energy Research Center, Oregon Sea Grant**

ENHANCING PERFORMANCE

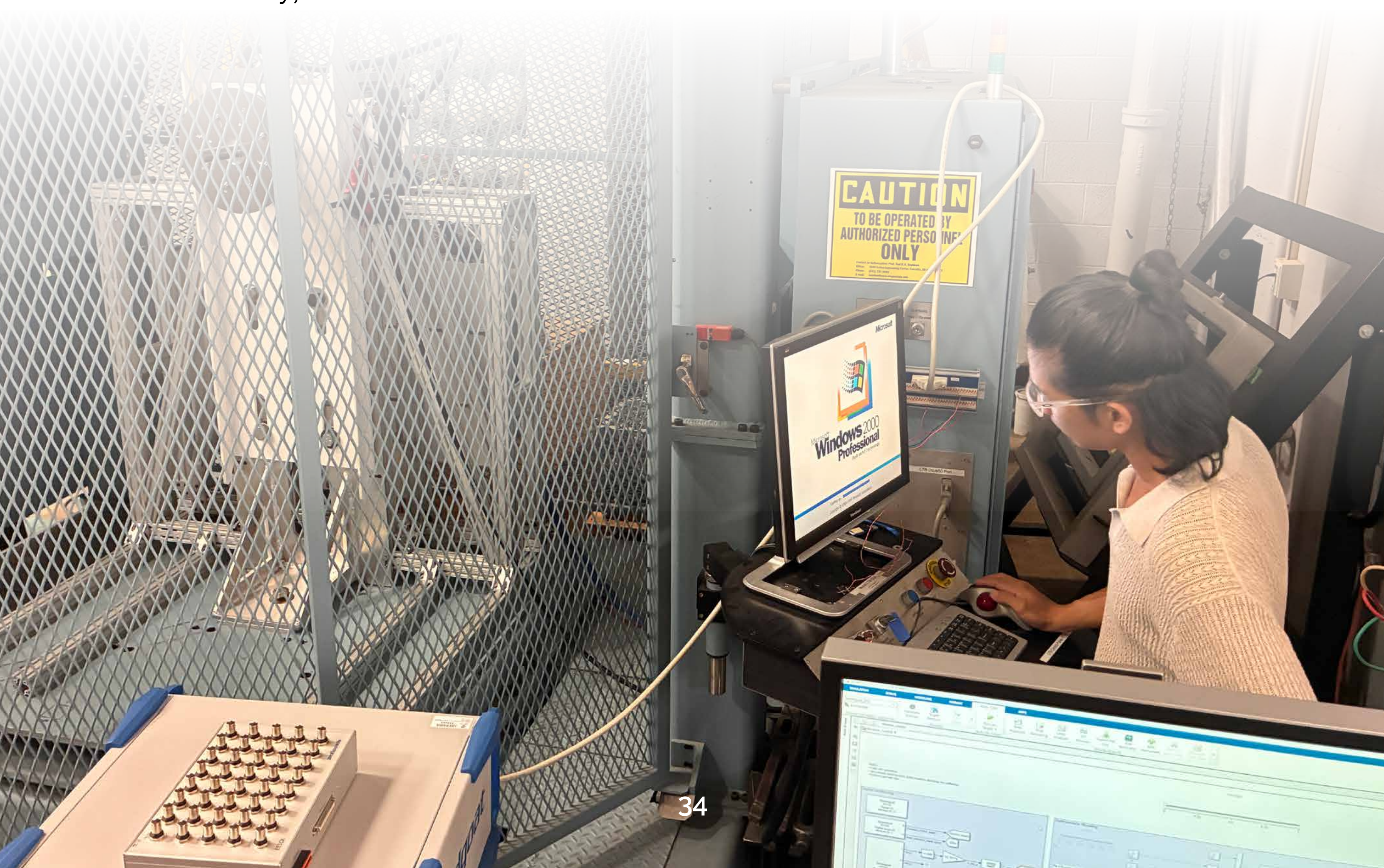
The stories in this section represent a subset of the 2025 research projects that build foundational knowledge to advance the performance and efficiency of wave and tidal energy conversion.

PREDICTING THE NEXT WAVE

“You need to understand how water behaves,” said Inyong Kim regarding his research in predicting ocean waves for energy conversion.

Kim is a PhD student in Electrical Engineering at Oregon State University, and co-manager of the Wallace Energy Systems and Renewables Facility (WESRF). He is investigating ways to improve the operation and control of wave energy converters (WECs) so that they can harness ocean energy more efficiently.

Wave energy conversion is fundamentally different from most forms of power generation. A gas-powered steam plant, a typical hydropower dam, or a tidal turbine all harness energy from unidirectional motion — rising steam, flowing water, or a tidal current — all spinning a turbine in a single direction. Ocean waves, on the other hand, come from all directions. Each individual wave is circular in motion, and waves arriving at a single location are constantly changing in height and frequency. So, research in wave energy conversion cannot make use of the decades of research on turbine efficiency; this field must innovate.



Kim's research applies to WEC control operations. Within a WEC, the mechanism that converts kinetic wave energy to electrical energy is the power take-off system (PTO). Most WECs have some form of damping in the power take-off to make them more or less resistive to movement. Effective use of the damping improves the efficiency of energy conversion. An analogy is the brake system in a vehicle. When driving a car into a steep bend in the road, a skilled driver will brake going into the bend, and then let up on the brake and accelerate into the curve. This type of brake control allows the vehicle to avoid jerking and flow smoothly around the bend. In a WEC, effective use of damping allows the device to resonate with the incoming wave and move optimally for maximum energy conversion.

Curtis Rusch, a PMEC alum and senior engineer with the University of Washington's Applied Physics Lab, describes this problem from a field operations perspective. He has been developing and testing point absorber WECs, most recently working with a device called TigerRAY in an industry collaboration with CPower. In the first test, the damping was too high. "Everything was stiff, it was like a rigid raft bobbing around, nothing was flexing," said Rusch. "Once we turned off the PTO entirely, in freewheel, everything was able to move very gently, but neither situation produced power. Getting to that happy medium of some damping, enough so you get current coming out of your generator is the balancing act."

Kim's research could take the guesswork out of that balancing act.

How does it do this? He developed a mathematical tool that predicts the frequency of the next incoming wave, in near real-time. Unlike previous algorithms used for this purpose, Kim's is computationally efficient. Efficiency is paramount: at sea, each watt matters.

"The mathematical tool that Kim is using to predict incoming wave frequency is a vector that rotates in complex space with a real and imaginary part, and the projection — or shadow — of that vector onto the real dimension, is made to match the real wave that we see," explained PMEC Interim Director Prof. Ted Brekken. This knowledge of the wave and the vector that represents it can inform how to adjust and control the WEC so that it resonates with the impinging waves for optimal energy conversion.

Number of students contributing to this project: 2
Funding: U.S. Dept. of Energy WPTO

2025 Collaborators

- 13 technology developers
- 3 national labs and test sites
- 8 non-PMEC universities
- 12+ non-profit organizations, government agencies, tribal communities, and utility cooperatives

SURVIVING EXTREME SEA STATES

Waves in the open ocean are created and driven primarily by wind energy, and consequently are most energetic at the air-sea interface. As a consequence of this, the vast majority of wave energy converter technologies today are designed to float on the surface to maximise their exposure to the potential and kinetic energy available for absorption. However, there is a flip side to this exposure to energetic waves - vulnerability to extreme storm conditions. A 2024 analysis of waves off the Oregon Coast at the PacWave test site, conducted by Junhui Lou and Bryson Robertson, found that while typical surface wave heights are between one to four meters, waves up to 14 meters high occur under extreme conditions (that's approximately the height of a four story building, three Tyrannosaurus Rex's standing on top of each other, or a Giant Squid). And since energy in a wave is proportional to the square of its height, these extremes pose significant risk to any surface-operating wave energy converter.

To drive design concepts towards resilience under the harshest ocean conditions, and limit their visibility from the shore (a concern for many coastal residents), researchers at OSU conducted and published extensive foundational research on subsurface wave energy conversion. They have categorized submerged WEC archetypes, identified capabilities and constraints of submerged WECs, analyzed power take-off and mooring system configurations, and published case studies and methodologies to assist stakeholders in selecting the best device for their application and location in the blue economy. This effort will continue through 2028 with novel prototype system construction, testing in the wave laboratories, and system optimization. See *Publications* to learn more.

Number of students contributing to this project: **5+**
Funding: **U.S. Dept. of Energy WPTO**

NEW TOOLS FOR CROSS-FLOW TURBINE DESIGN

While the orbital movement of ocean waves has inspired a wide variety of designs for wave energy converters, tidal turbine design conforms to two primary schemas: axial-flow turbines (like those used commonly in windfarms), and cross-flow turbines, which have an axis of rotation that is perpendicular to the flow direction, like the Turbine Lander on page 11.

Compared to conventional axial-flow turbines, cross-flow turbines offer several advantages in the tidal environment: they operate at lower rotation rates, they do not require reorientation when the tidal current reverses direction, and could have synergistic effects if deployed in arrays. In 2025, PMEC's researchers at UW published results from several new laboratory and modeling studies that advanced fundamental understanding of the flow physics, performance characteristics, and optimal design of cross-flow turbines.

A turbine operating in a tidal channel is influenced by how much of the channel it occupies, commonly referred to as the turbine's "blockage." When it takes up more space, the power output increases, but so do the structural loads experienced, which can drive up costs. What is the sweet spot between increased power generation and increased costs? To help answer this question, PMEC Senior Research Engineer Aidan Hunt led laboratory experiments studying the hydrodynamics, design, and control of high-blockage turbine arrays. The results of these studies provide pathways for optimizing cross-flow turbines for high-blockage environments and leveraging analytical models to interpret their performance.

When designing a cross-flow turbine, engineers must specify several parameters of the rotor geometry—such as the blade size, profile, and pitch angle—whose combined effects influence turbine performance. However, as the blades rotate, their curved trajectories distort the blade's shape and angle of attack when viewed from the perspective of the incoming flow. These "flow

curvature" effects influence turbine efficiency, but have historically been neglected in the design process due to their complexity. Ari Athair, a PhD candidate in the Aeronautics and Astronautics Engineering department at UW, characterized the performance of cross-flow turbine rotors with different combinations of blade chord length, camber, and pitch angle to show how these effects interact. Contrary to convention, the work shows that the use of cambered blades (those with an asymmetric cross section) is an effective pathway to increase efficiency and reduce loading compared to conventional symmetric blades. This work paves the way for informed designs that optimize a combination of blade chord length, camber, and pitch angle.

Yet another study bridges a gap between theory and practice in turbine performance. Theoretical study of turbine blades have focused on a set of metrics that describe the forces and torques on a given blade. However, this knowledge hasn't been leveraged in the design process, in large part because, in practice, turbine performance is measured at its output shaft, not at the blades themselves. This disconnect has resulted in significant challenges building predictive models of turbine performance that can be used for design. Identification of blade-level forces and torques allows for specific investigations into how the fluid forcing on the blade drives rotation and can aid blade structural design. PMEC alum Abigaile Snortland (currently a postdoctoral scholar at Pacific Northwest National Laboratory), together with PMEC colleagues, created a method to estimate blade-level performance metrics using only turbine output shaft data. This method can now be utilized for a wide range of turbines. Perhaps most crucially, her analysis suggests that the location of the center of pressure on the blade has a significant effect on turbine hydrodynamics. The rotational load that represents this effect, known as the "pitching moment", is often neglected in models of cross-flow turbines, but was shown by Snortland to have a significant detrimental effect on turbine efficiency.

> *"The most exciting part of this research, for me, was finding a way to connect all these little pieces explored by others into a more cohesive method to improve crossflow turbine designs. Prior work has investigated several design parameters independently, but connecting the dots and seeing how they interact in concert was very satisfying." — Ari Athair*

> *"My favorite outcome of these experiments is that we demonstrated that relatively simple models can describe certain salient hydrodynamics of these cross-flow turbines and trends across different rotor designs, even though their fluid dynamics are complicated and unsteady." — Aidan Hunt*

> *"Extracting the forces acting on the blades of cross-flow turbines reveals details about how they work that you can't see by only looking at forces and torque at the main shaft. For example, we show that the pitching moment on the blades—often ignored in past research—actually hinders turbine performance, and this kind of insight can guide research into new ways to improve cross-flow turbines." — Abigale Snortland*

See *Publications* for more information.

Funding: U.S. Dept. of Energy ARPA-E SHARKS

Lab and Field Projects Completed in 2025:

- Applied research and development to support open water testing at PacWave
- Completed a river resource and siting study during open water season at McGrath, Alaska
- Concluded a collaborative research project in St. George, Alaska, giving new insight into how marine energy could strengthen energy resilience in Alaska's coastal and island communities
- Completed a resource assessment and report for site characterization in Rosario Strait
- Measured the acoustics of CPower's SeaRAY at the Wave Energy Test Site (WETS)
- Improved turbine blade designs and validated openFAST models with field data
- New facility capability: RV Light Research Vessel-based fiber optic measurements of strain along a turbine blade during operation, to determine blade deformation
- New facility capability: Digital Image Correlation of turbine blades during operation in the Alice C. Tyler Flume

SHAPING THE NEXT GENERATION OF MARINE ENERGY LEADERS

PMEC strives to create and support ample opportunities for networking as students launch their careers. For example Ali Trueworthy, currently a postdoctoral scholar at Pacific Northwest National Laboratory, met her current mentor at a PMEC All-Center Meeting. Morel Arango's advisor introduced him to colleagues who were co-founding BladeRunner Energy, where Moriel is now CEO and CTO. This company is collaborating with PMEC researchers to provide river current power to remote communities in Alaska (see the research highlight in *Powering Communities*). In 2025, we compiled information on the career paths of PMEC graduates over the past 14 years and caught up with a few alums.

From 2009 to 2025, over 126 students have completed graduate degrees with a PMEC-affiliated advisor. About two thirds of those students earned a master's degree, the other third earned a doctorate. These alumni have gone on to a variety of career paths, including roles in industry and at national laboratories, non-profits, government, and universities. The percentages show the career paths that our alumni have chosen. Take a look at some examples of employers from each category:

- **23.8 %** → **Industry - Ocean Engineering + energy:** Glosten, MarineSitu, CPower, Moffat & Nichol
- **18.0%** → **National Labs:** Pacific Northwest National Laboratory (PNNL), Sandia National Laboratories, and the National Laboratory of the Rockies (NLR)
- **16.6%** → **Industry - Other:** robotics, tech, consulting, GIS mapping, and software engineering companies including Boeing, AWS, and Alphabet
- **13.5 %** → **Industry - Energy (non-marine):** hydropower, wind power, electric utilities including Bonneville Power Administration, Blook Energy, Tetra Tech, Canyon Hydro
- **5.9%** → **Government:** California Coastal Commission, LA Department of Natural Resources, US Navy, US Army Corps of Engineers, NOAA, Department of Energy
- **5.8 %** → **Non-profit:** Global Fishing Watch, the Ocean Exploration Trust, Renewable Northwest
- **4.9 %** → **University:** University of Washington, University of Rochester, University of Oslo, University of Massachusetts, Oregon State University, Everett Community College

Ali Trueworthy, PhD

Postdoctoral Research Associate
Pacific Northwest National Laboratory
Graduation Year: 2024, Oregon State University

What do you do?

Community technical assistance for energy projects in the Pacific Northwest and Alaska, and research on approaches to community-based energy projects.

What's something you love about working in this sector?

I love the connection between energy systems, people, and the land. When thinking about strategies for making change, you have to know the things that make specific places and communities what they are. It is rewarding to help people trace the lines between the things they care about and the actions that they can take.

How did your experience with PMEC influence your career trajectory?

My experience with PMEC introduced me to the people that I continue to work with. I met my current mentor, Molly Grear with PNNL, at the virtual all-center meeting in 2020. Getting to work in Sitka, AK through the ORISE fellowship was the highlight of my graduate school experience.

What skills and/or experience would you recommend people gain if they want to work in marine energy or related fields?

I would recommend people practice catering their work to their audience. Not just by learning how they communicate their work, but also by learning how to adopt and adapt methodologies to fit the scenario they are faced with.

Moriel Arango, MS

CEO & CTO
Bladerunner Energy, Inc.
Graduation Year: 2011, University of Washington

What do you do?

I lead a small team of engineers at BladeRunner Energy that develop hydrokinetic technologies. We're developing a river current system for applications in remote river communities and, more recently, have started work on a tidal energy system.

What's something you love about working in this sector?

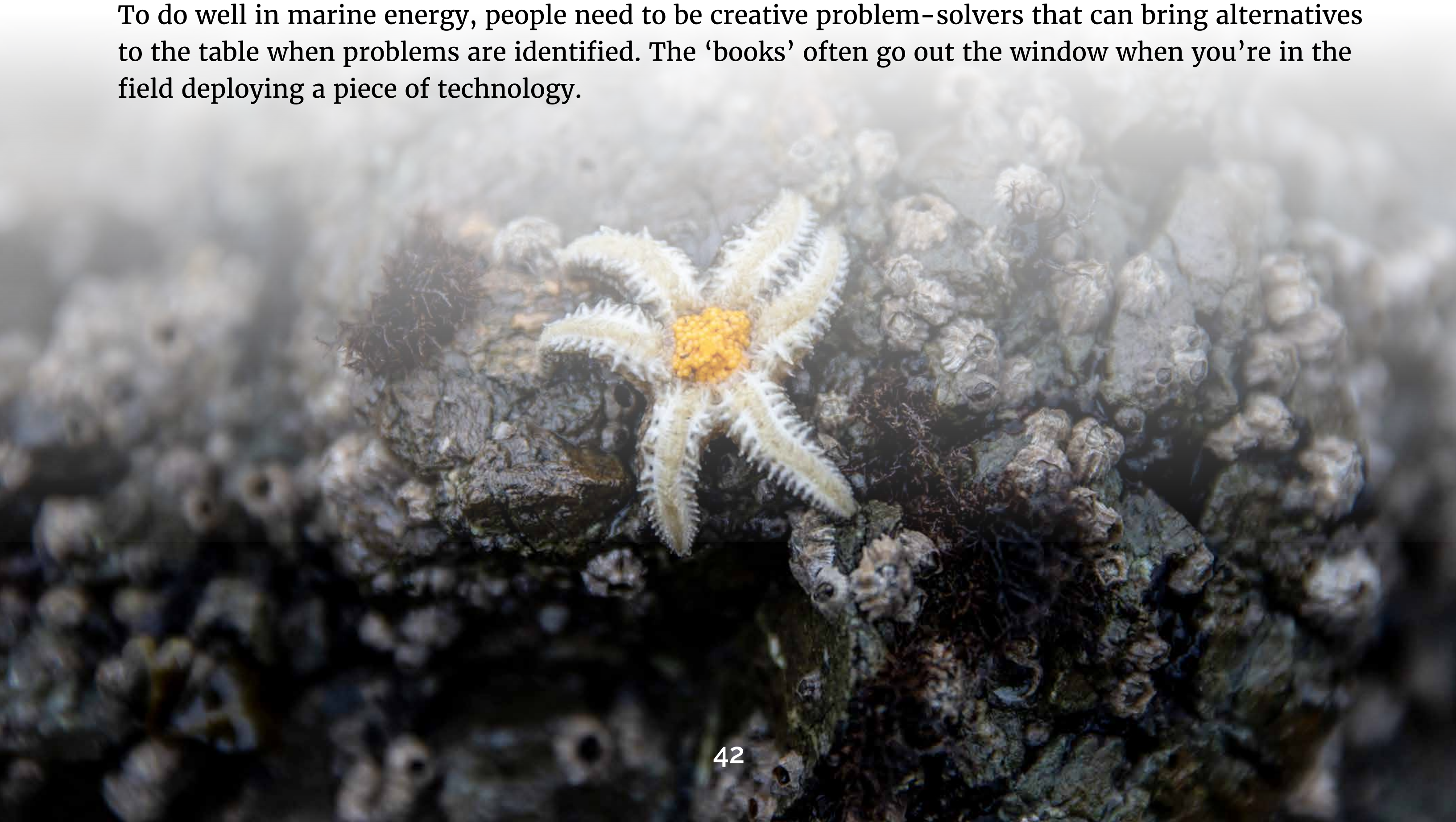
I enjoy working on technology that offers both an engineering challenge with opportunities for creativity and the potential to have a positive impact.

How did your experience with PMEC influence your career trajectory?

My advisor, Dr. Phil Malte, the former co-director of PMEC, introduced me to one of the co-founders of BladeRunner Energy. After a number of years of staying in contact with them and thanks to the experience and knowledge on hydrokinetics that I gained through my involvement with PMEC, I was a good fit to join the BladeRunner Energy team when I did.

What skills and/or experience would you recommend people gain if they want to work in marine energy or related fields?

To do well in marine energy, people need to be creative problem-solvers that can bring alternatives to the table when problems are identified. The 'books' often go out the window when you're in the field deploying a piece of technology.



Ben Strom, PhD

CTO & Cofounder
XFlow Energy
Graduation Year: 2018, University of Washington

What do you do?

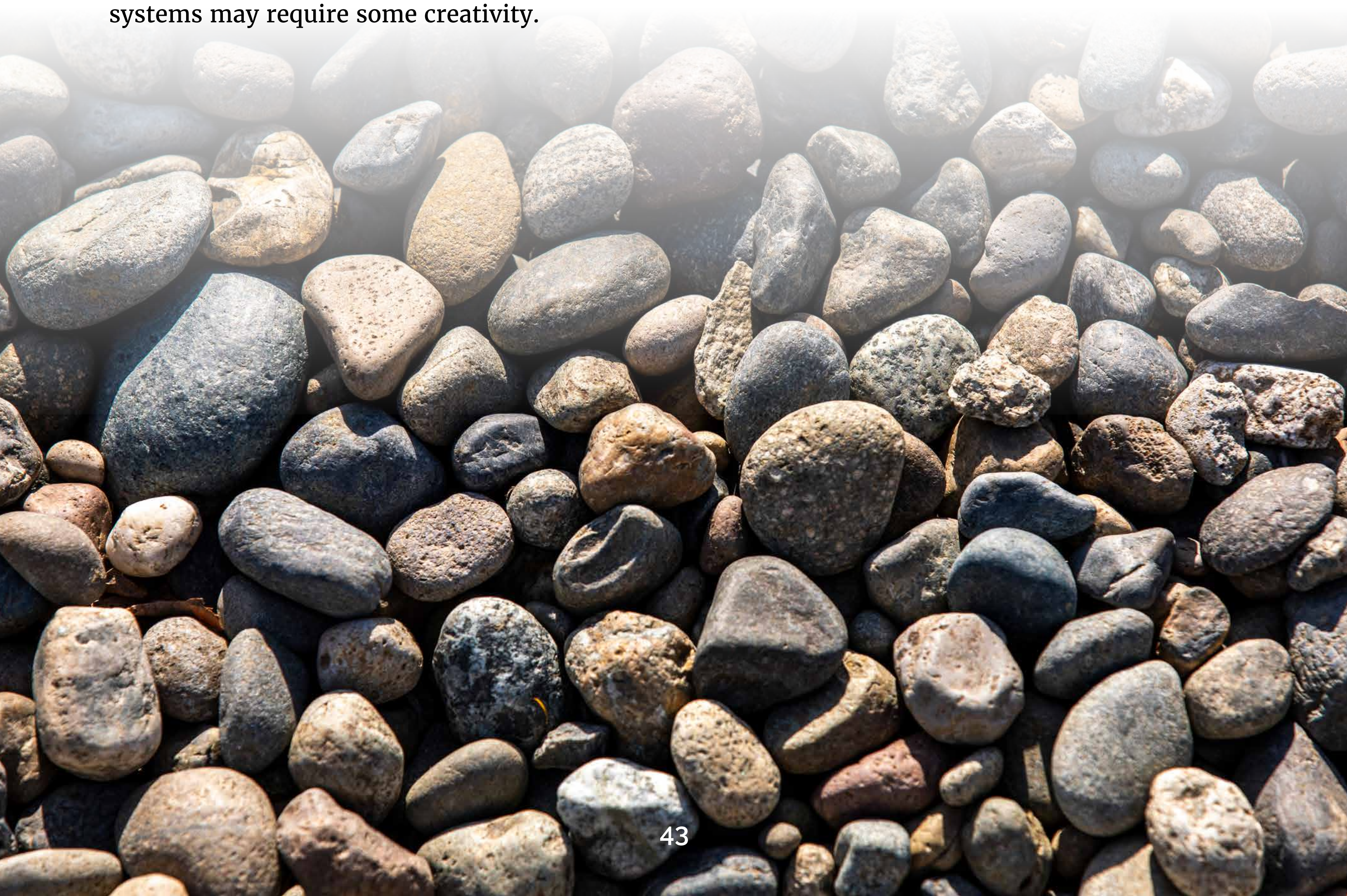
I lead research and development of vertical-axis wind turbines and power conversion and control systems for wind and water turbines.

What were some highlights of your PMEC experience?

We had an amazing community of students and PIs, who were a pleasure to work and recreate with. My community of friends today includes many former PMEC members.

What skills and/or experience would you recommend people gain if they want to work in marine energy or related fields?

Folks with strong analytical and practical engineering capabilities are few and far between. If you have a chance to develop both, I highly recommend it! The academic environment often emphasizes analytical development, so learning things like design for manufacturing or electrical control systems may require some creativity.



James Joslin, PhD

CEO & Principal Engineer
MarineSitu
Graduation Year: 2015, University of Washington

What do you do?

Our company develops and provides underwater monitoring technologies. As the CEO, I lead our product and project design efforts, as well as business development and financing. I am also the lead mechanical engineer on our team.

What's something you love about working in this sector?

We get to work on interesting problems in exciting places and address unique data and instrumentation challenges.

How did your experience with PMEC influence your career trajectory?

Through PMEC I developed the background technology and network that allowed me to start MarineSitu and spin the company out of UW.

What skills and/or experience would you recommend people gain if they want to work in marine energy or related fields?

Hands-on experience in the field is invaluable and working with PMEC allows for a lot of opportunities to get out and work with instruments and marine energy systems. I would strongly encourage everyone to take advantage of these opportunities as often as possible.

2025 GRADUATIONS

INSTITUTION	NAME	DEGREE	THESIS or PROJECT
UAF	Kawsar Ahammed	MS	Electric Power Regulation for a Novel Riverine Hydrokinetic Energy Conversion System
UW	Brittany Lydon	PhD	Data Driven and Experiental Modeling of an Oscillating Wave Energy Converter
OSU	Courtney Beringer	PhD	Connecting theory to application: exploring degree of freedom effects and uncertainties in wave energy converter model testing
OSU	Nick Cruz	MS	Think big, build small : the design, modeling, and testing of a small-scale submerged pressure differential wave energy converter
OSU	Emily Miller	MS	The Promise and Practice of CBMs: Community Perspectives on Benefit Mechanisms in U.S. Offshore Wind Development
OSU	Matthew Gschwend	MS	Inflate, Deflate, Generate: The Development and Testing of a Submerged Deformable Membrane Wave Energy Converter
OSU	Hannah Mankle	PhD	Statistical representation of waves in free-surface elevation time series
OSU	Taufiq Hossain	PhD	Community Benefit Mechanisms and the Public Policy Process in Ocean Renewable Energy: Fairness, Transparency, and Local Acceptance in U.S. Coastal States
OSU	Sam Barton	PhD	Reinforcement Learning-Based Control for Improving Resiliency in Hydrokinetic Turbine Systems
OSU	Makenna Cubic	MS	Patterns of Civility and Incivility in Statehouses: New Evidence from the Outside Looking In Project

NEW IN 2026: MARINE ENERGY SHORT COURSES

In 2026, PMEC will launch a variety of marine energy short courses for undergraduate and graduate students who are interested in careers in marine energy or simply want a better understanding of the field.

The Alaska Center for Energy and Power (ACEP) at University of Alaska, Fairbanks will offer two experiential short courses in 2026: **Field Work and Fish**, a 7-10 day intensive course for graduate students with classroom lessons on campus and fieldwork at the Tanana River Test site. Students will learn fundamentals of riverine resource characterization, environmental monitoring, and practices for testing river current devices. **Introduction to Marine Energy**, a 5-day undergraduate course taught both on campus in Fairbanks and in Nenana, Alaska. It will provide basic principles of marine energy and all of its associated disciplines. These courses will be open to students across the US with travel funding available.

The University of Washington will offer a 2-week **Introduction to Marine Energy** for advanced undergraduates across the UW campuses (Tacoma, Bothell, and Seattle). The course will include lectures and activities focused on marine energy fundamentals with additional materials covering ocean instrumentation, ocean engineering, and the marine energy converter design. Students will be exposed to prototype (small field-scale) marine energy converters, the engineers that designed them, and will have the opportunity to deploy one of them on Lake Washington.

Oregon State University is developing courses with content in ocean dynamics and floating structures, energy conversion and modeling, grid integration, and moorings. The OSU team is currently creating an online course on power electronics for non-electrical engineers for deployment through the OSU Office of Professional and Continuing Education in the summer of 2026.

ANNOUNCING THE 2026 INTERIM DIRECTOR

Ted Brekken

OSU Professor
Interim PMEC Director

In the final weeks of 2025, we celebrated the appointment of PMEC's 2026 Interim Director Ted Brekken, a professor of Electrical Engineering and Director of the Wallace Energy Systems and Renewables Facility (WESRF) at Oregon State University. Brekken was previously an associate director of PMEC.

> *"The thing I find most exciting about working with PMEC is the community of researchers. It's a genuinely engaged and exciting group of people, showing up because they are interested in the technology, interested in the policy, and interested in the people. It's very energizing to work with this welcoming group. PMEC is building bridges to other communities as well as bridges within itself between researchers and students in different disciplines, and I'm extremely proud of the fact that it's growing students and experts in the field."*

Brekken giving a tour and demonstration of the WESRF Facility to marine energy researchers and industry leaders, August 2025.

SELECTION OF 2025 PUBLICATIONS AND CONFERENCE PROCEEDINGS

The content below is a non-comprehensive list of PMEC publications from 2025 referenced in this report, and does not include the many publications submitted and accepted in 2025 which will be published in 2026.

TURBINE LANDER & THE AMP

Bassett, C., Gibbs, P., Wood, H. Cavagnaro, R.J., Cunningham, B., Dosher, J., Joslin, J., & B. Polagye, B. (2025). Lessons learned from the design and operation of a small-scale cross-flow tidal turbine. Journal of Ocean Engineering and Marine Energy.
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Bassett, C., Wood, H., Gibbs, P., Cunningham, B., Dosher, J., & Tran, T. (2025). The 2nd Generation Turbine Lander: Design, Analysis, and Testing. Technical Report, APL-UW TR 2503. Applied Physics Laboratory, University of Washington, Seattle, September 2025, 59 pp.

Bassett, C. and Cotter, E. (2025). Observations of fish, birds, and harbor seals around an operating cross-flow turbine. 16th European Wave and Tidal Energy Conference, Maderia, Portugal, September 7–11, 2025. https://doi.org/10.36688/ewtec-2025-907

WAVE POWERED AUTONOMOUS UNDERWATER VEHICLES

Lou, J, Okushemiya, D, & Robertson, B. (2025). Wave Distortion Methodology for Experimental Mixed-Scale Testing of Underwater Vehicle Docking. Proceedings of the ASME 2025 44th International Conference on Ocean, Offshore and Arctic Engineering. Volume 3: Ocean Engineering; Polar and Arctic Sciences and Technology. Vancouver, British Columbia, Canada. June 22–27, 2025. V003T06A041. ASME. https://doi.org/10.1115/OMAE2025-156599

Ni, Y., Seki, A., Bosma, B., Brekken, T., Robertson, B., Schellenberg, A., ... & Simpson, B. (2025, August). A Robotic Actuation Approach for 6-DOF Force Control in Hydrodynamic Real-Time Hybrid Simulation. In 2025 IEEE 21st International Conference on Automation Science and Engineering (CASE) (pp. 3211-3216). IEEE. https://doi.org/10.1109/CASE58245.2025.11164156

LISTENING IN THE RIVER: NEW DAISY MEASUREMENTS

Polagye, B., Hunt, A., Mackey, L., and Bassett, C. (2025). Approaches to attributing underwater noise to a wave energy converter. JASA Express Lett. 1 May 2025; 5 (5): 056004.
https://doi.org/10.1121/10.0036727

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https://doi.org/10.1007/s40722-024-00358-6

COMMUNITY BENEFITS AND ENERGY DEVELOPMENT

Binghman, J., E. Miller, Lorren Ruscetta, H. A. Taufiq, G. Stelmach, J. Firestone, T. R. Johnson, S. Hazboun, H. Boudet (2025). Understanding the roles, limits, and best practices for community benefit agreements in U.S. offshore wind development. Science Direct. Vol. 268, September 2025, 107769.
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Tighsazzadeh, M., Doyon, A., Hirsch, S., and Cisneros-Montemayor, A. (2025). The evolution of equity in offshore renewable energy: A systematic literature review. Ocean & Coastal Management, 263, 11.
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Trueworthy, A., DuPont, B., and Grear, M. (2025). Transforming transitions: The energy futures of community-driven design, Renewable Energy, 242, 122470.
https://doi.org/10.1016/j.renene.2025.122470

PREDICTING THE NEXT WAVE

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SURVIVING EXTREME SEA STATES

Ali, R., Roach, A., Bosma, B., Robertson, B. (2025). Impact on power generation and numerical comparison of experimentally observed subharmonic motions of a submerged point absorber wave energy converter. 16th European Wave and Tidal Energy Conference, Funchal, Portugal, September 7–11, 2025.

Ali, R.; Meek, M.; Robertson, B. (2025). Submerged wave energy converter dynamics and the impact of PTO-mooring configuration on power performance. Renewable Energy, 243, 122525. https://doi.org/10.1016/j.renene.2025.122525

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Cruz, N, Gschwend, M, Piacenza, J., Yim, S, and Kruniawan, A. (2025). Inflate, Deflate, Generate Part II: Design and Modeling of a small-scale submerged pressure differential wave energy converter. Proceedings of the ASME 2025 44th International Conference on Ocean, Offshore and Arctic Engineering. Volume 5: Ocean Renewable Energy. Vancouver, British Columbia, Canada. June 22–27, 2025. https://doi.org/10.1115/OMAE2025-156178

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NEW TOOLS FOR CROSS-FLOW TURBINE DESIGN

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Li, P. and Y. Cao (2025). A Post-fault MPPT Control with Multi-Physics Evaluation Framework for Fault-tolerant Hydrokinetic Turbine Drivetrain. IEEE Transactions on Industry Applications. doi: 10.1109/TIA.2025.3634047.

Loeffler, B., Duvoy, P., Kasper, J., and Denkenberger, D. (November 19, 2025). "Field Investigation of Bluff Body, Spring, Damping, and Mechanical Rectification Performance Impacts on a Galloping Current Energy Converter." ASME. J. Offshore Mech. Arct. Eng. April 2026; 148(2): 022001. https://doi.org/10.1115/1.4069998

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Snortland, A., A. Hunt, O. Williams, and B. Polagye (2025). Influence of the downstream blade sweep on cross-flow turbine performance. Journal of Renewable and Sustainable Energy, 17, 013301. https://doi.org/10.1063/5.0230563

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ADDITIONAL PAPERS ON WAVE ENERGY CONVERSION

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Bosma, B., Beringer, C., Coe, R., Baccelli, G., Gaebele, D., Forbush, D., & Robertson, B. (2025, September). System identification techniques applied to a laboratory scale WEC point absorber. In Proceedings of the European Wave and Tidal Energy Conference (Vol. 16). https://doi.org/10.36688/ewtec-2025-826

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Gaebele, D., Coe, R., Bacelli, G., Forbush, D., Bosma, B., Beringer, C., ... & Lomonaco, P. (2025, June). Streamlined Experimental Approach to System Identification of WEC Dynamics and Excitation Characteristics. In International Conference on Offshore Mechanics and Arctic Engineering (Vol. 88940, p. V005T09A055). American Society of Mechanical Engineers. https://doi.org/10.1115/OMAE2025-156997

Gschwend, M (2025). Inflate, deflate, generate : the development and testing of a submerged deformable membrane wave energy converter. OSU Dissertation

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RESOURCE ASSESSMENTS

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The following individuals generously contributed content or editorial review: Chris Bassett, Emma Cotter, Bryson Robertson, Luke Woodhouse, Brian Polagye, Sarah Henkel, Aidan Hunt, Owen Williams, Yuri Bult-Ito, Shawn Hazboun, Brenda Langley, Anna Herring, Ted Brekken.

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