U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Summary Report: October 5, 2021 Workshop on Materials & Manufacturing for Marine Energy Technologies

May 2022

Water Power Technologies Office

Disclaimer

Preface

The U.S. Department of Energy's Water Power Technologies Office (WPTO) enables research, testing, development, and commercialization of emerging technologies to advance marine energy, as well as next-generation hydropower and pumped storage systems, for a flexible, reliable grid. This report summarizes the results of a WPTO-sponsored public workshop held virtually on October 5, 2021.

Authors

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Acknowledgments

WPTO would like to thank those who participated in the workshop; hosts Carrie Noonan of WPTO and Bernadette Hernandez-Sanchez of Sandia National Laboratories; and workshop organizers Kathleen Morton and Megan Lennox of the National Renewable Energy Laboratory.

WPTO also thanks the following for their contributions to breakout session content:

- DOE facilitators: Lauren Ruedy, Steve DeWitt, Erik Mauer, Elaine Buck, Bill McShane, Elizabeth Hjelvik, and Laura Rios
- National laboratory facilitators: Sandia National Laboratories (Vince Neary, Kailey Wulfert, Irene Trujillo, Jesse Roberts, Kelley Ruehl, Ryan Hess); Oak Ridge National Laboratory (Dawn White); Pacific Northwest National Laboratory (Rob Cavagnaro); and the National Renewable National Laboratory (Blake Boren)
- Advanced materials team: Sandia (Hannah Narcross, Budi Gunawan); National Renewable Energy Laboratory (Scott Hughes, Paul Murdy); Montana State University (David Miller); and Pacific Northwest National Laboratory (George Bonheyo)
- Scribes: DOE (Charlene Goldman, Terri Krantz) and Sandia (Dylan Poindexter, Sterling Hamilton Violette, Avery Serda, Eun-Kyung Cho Koss).

List of Acronyms

CEC	current energy converter
DOE	U.S. Department of Energy
FSI	fluid-structure interaction
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
ORPC	Ocean Renewable Power Company
R&D	research and development
Sandia	Sandia National Laboratories
WEC	wave energy converter
WPTO	Water Power Technologies Office

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1 Introduction

Marine energy technologies have the potential to play a critical role in the effort to equitably transition America to net zero greenhouse gas emissions economywide by no later than 2050. Large and geographically diverse, the nation's total potential marine energy resource is 2,300 terawatt-hours annually, equivalent to approximately 57% of 2019 U.S. generation. This energy lies predominantly in waves and tides off coastlines and in rivers.

Marine energy technologies have not yet reached cost competitiveness with other energy resources. To scale commercially, dramatic cost reductions are needed over the next 10 to 20 years. The Water Power Technologies Office (WPTO) Marine Energy Program's foundational research and development (R&D) activity—one of WPTO's four core R&D activity areas—supports efforts to drive these cost reductions by improving existing device designs and performance. The program also investigates capabilities to enable entirely new designs and approaches for harnessing the energy in natural water bodies. These early-stage R&D efforts are typically applicable to a wide range of device types and, in some cases, cut across multiple resource types (e.g., wave, tidal, ocean current) and subsystems.

One subactivity area under the Marine Energy Program's foundational R&D activity is materials and manufacturing, in which new capabilities have the potential to drive significant cost and performance improvements in marine energy technologies through increased energy capture and reduced costs. As depicted in Figure 1, this subactivity supports basic and applied R&D of materials and manufacturing that can: (1) increase longevity/reduce operation and maintenance costs; (2) reduce capital costs; and (3) improve energy capture.

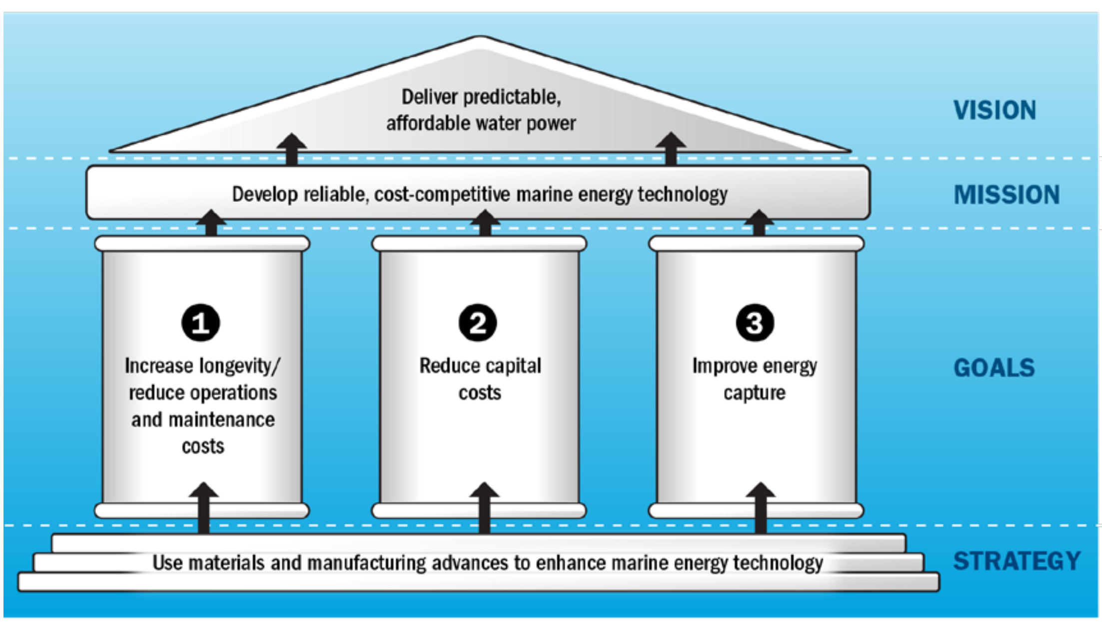

Figure 1. WPTO's vision for materials and manufacturing in marine energy

Since 2008, WPTO and the U.S. Department of Energy (DOE) national laboratories, partnering with academia and industry, have conducted foundational marine energy R&D in areas such as biofouling, corrosion, structural health monitoring, environmental effects on composites, nanomaterial development, and protective coatings development. Other studies of critical components, such as turbine blades and moorings, have indirect implications for materials research. In parallel, several important groups outside the United States have been conducting extensive R&D in marine energy materials and manufacturing, including explorations of device structure, mooring, components, and environmental and operational effects.

While the national labs and international organizations have provided significant direction on technical gaps in marine energy research for the materials and manufacturing space, WPTO recognizes that having additional perspective from industry and academia provides a more comprehensive understanding of R&D needs. To capture industry and academia input, WPTO held a four-and-a-half-hour virtual workshop on materials and manufacturing R&D investments for wave and current energy technologies. More than 100 participants from academia, industry, and DOE national research labs joined the workshop (access additional webinar information here). A breakdown of the attendee organizations follows:

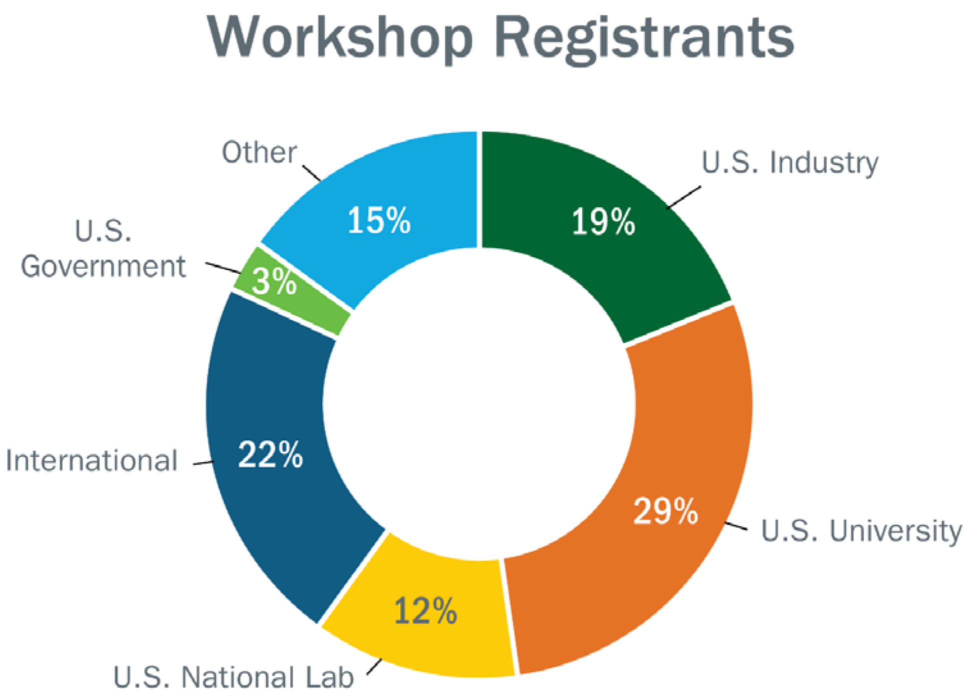

Figure 2. Breakdown of workshop registrants by organization type

1.1 Workshop Structure

In the first part of the workshop, several industry and university partners presented materials projects and identified gaps that currently prevent marine energy devices from reaching commercial viability. The workshop focused on three major research areas: current energy converters (CECs), conventional wave energy converters (WECs), and unconventional WECs. The workshop format was as follows:

- **Introduction:** Marine Energy Technologies: The Materials Landscape (DOE and national laboratories)

- **Part I:** Marine Energy Materials Project Presentations
- **Part II:** Breakout Discussions
    - Breakout Discussion 1: Wave Energy Converter (WEC) Needs
    - Breakout Discussion 2: Tidal and Current Energy Converter (CEC) Needs
    - Breakout Discussion 3: Unconventional WECs and Other Needs
- **Part III:** Report Out and Closing.

After the Part I presentations, attendees participated in breakout discussions to identify key R&D activities for future WPTO materials and manufacturing funding investments across the three research areas. The breakout panels culminated in a "report-out" session, where each group shared a summary of recommendations from the breakout discussions.

2 Marine Energy Materials Project Presentations

In Part I of the workshop, nine participants delivered presentations on marine energy materials research projects in either the WEC or CEC area. Each presentation lasted 3–5 minutes with 5 minutes allotted for questions and answers. A summary of the presenters, topics, and identified gaps follows.

2.1 University of Edinburgh, United Kingdom

Ed McCarthy, Lecturer in Composites Design and Testing

Ed McCarthy discussed work on various aspects of tidal turbine blades through three different projects at the University of Edinburgh. The FASTBLADE Structural Composites Research Facility, currently under construction at Rosyth Harbor north of Edinburgh, is the world's first tidal turbine blade high-cycle fatigue test facility for blades and other beam structures up to 12 meters (39 feet) long. The POWDERBLADE project, completed in 2019, piloted the use of powder epoxy materials for the production of offshore wind blades, which is a technology readily transferable to tidal blades. Finally, a new project with the Institute of Energy Systems in Edinburgh involves researching composite material development options to facilitate passive morphing of tidal blade trailing edges.

Based on these three projects, the University of Edinburgh identified three materials project needs for the CEC sector: improved first-day manufacturing quality of composites, which requires a combination of better materials and processes; tougher yet more flexible materials capable of supporting more sophisticated function; and more materials testing at meaningful scales.

"Resin toughness is a big issue. Traditionally, we've inherited a system of resins that are quite brittle, with relatively low strain to failure." —Ed McCarthy, University of Edinburgh

2.2 Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), France

Peter Davies, Marine Structures Laboratory Researcher

"We can look at how the environment affects the composites, but we also need to look at how these materials are affecting the environment. We think that is an important part which has to be included in any long-term program to look at material needs." —Peter Davies, IFREMER

Peter Davies described findings from the RealTide project, which is evaluating composites for tidal turbine blades, the Polyamoor project, which concluded in 2020 and studied the durability of synthetic mooring lines, and an internal IFREMER project evaluating environmentally friendly materials for marine energy. Among the results of this research, Davies noted that polyamides were validated for moorings and that an increasing range of alternative materials, including natural fibers, cellulose, and bio-sourced polymers, are available and should be evaluated both in terms of properties for marine energy and life cycle analysis.

Overall, Davies concluded that additional data on durability and fatigue is needed, and that collaboration is essential given that generating relevant data under representative conditions is time- and machine-consuming. A multi-partner program would fill these gaps and establish confidence that materials used in CEC and WEC devices can survive harsh marine energy conditions.

2.3 Verdant Power, United States

Jonathan Colby, Director of Technology Performance

"Thermoplastic materials have the potential to be a game changer for the industry." —Jonathan Colby, Verdant

Jonathan Colby discussed the Thermoplastic Composite Blade Research Measurement Campaign, a partnership with Verdant, the National Renewable Energy Laboratory, Sandia National Laboratories (Sandia), and Pacific Northwest National Laboratory. The project's goal was to characterize thermoplastic composite blades for the marine energy sector, from coupon scale all the way to the full-scale rotor. The campaign leverages the DOE-funded TriFrame project, which involves retrieving and replacing a turbine deployed in New York's East River.

Through this work, researchers were able to characterize the structural performance of both traditional epoxy and thermoplastic composite blades. Among the top materials needs identified were an improved understanding of adhesives and joints; an improved understanding of water penetration in composites and core structures; more recyclable materials; and investigations of maintenance needs for coatings and biofouling as applied to thermoplastics and thermosets. Verdant had additional ideas on longer-term research needs in the area of self-healing material, improved structural monitoring to enhance reliability, and the increased use of machine learning to improve component-level manufacturing.

2.4 Ocean Renewable Power Company, United States

Matthew Barrington, Mechanical Engineer

> "Fluid-structure interaction models are critical to come up with the next generation of turbine designs, both for hydrodynamics and structure." —Matthew Barrington, ORPC

Matthew Barrington gave an overview of Ocean Renewable Power Company's (ORPC's) RivGen Power System, which was deployed in Alaska in 2019. Findings from that project led to the successful build of a second-generation turbine. He also discussed ORPC's high-deflection foil research and structural health monitoring work, which considered how deflection affects the performance of a cross-flow turbine.

Barrington said the key materials needs for tidal turbines include cost-effective manufacturing options for composites, which could include helical pultrusion and vacuum infusion that incorporates a thermoplastic resin. He also encouraged further research into additive manufacturing, such as large metal/titanium 3D printing, and casting. Cloud computing costs for fluid-structure interaction (FSI) modeling and optimization, Barrington added, are prohibitively expensive but are critical in the materials and manufacturing space.

2.5 CalWave Power Technologies, United States

Nigel Kojimoto, Lead Mechanical Engineer

> "Being in a relatively early to [middle] stage, we're in the process of finding the very first solutions to our problems and not quite in a state where it's easy for us to put a lot of effort and focus into finding an optimized solution for the whole structure."—Nigel Kojimoto, CalWave

Nigel Kojimoto discussed CalWave's Winching Belt Cyclic Bend Over Sheave testing work in the WEC area. One of the challenges of CalWave's winch system is to have a tension member within the system that can withstand the full number of cycles the company's device would experience when deployed. Since 2019, CalWave has conducted testing of high-modulus polyethylene and polyurethane winching belt options in separate projects with IFREMER and Sandia, respectively.

CalWave identified the need for methods to integrate materials projects into existing/future funded projects, because it is difficult to prioritize material improvements in large projects. He also expressed a need for funding opportunities that materials manufacturers can apply for that encourage collaboration with device developers.

2.6 Aquantis, United States

Peter Stricker, Strategy Leader

"We're really trying to step back and look at this whole thing from the standpoint of, 'These are the standards. How can we approach this from a different angle?'"— Peter Stricker, Aquantis

Peter Stricker discussed work under a DOE contract to explore cementitious materials to form vessel and potentially blade structures for tidal turbines. The challenge with cementitious material is its low tensile strength, he said, but its attributes include good compressor strength, high corrosion resistance, and low cost. Initial exploratory testing has shown modest flexure and tensile strengths, but the project is just beginning.

The top materials project needs identified by Stricker include submerged strength and fatigue testing for turbine blades; performance testing in terms of loads, cavitation, corrosion, and fouling resistance; and support to develop novel material handling and forming methodologies.

2.7 Wave Energy Scotland, United Kingdom

Matthew Holland, Project Engineer

"We need to think more about how to design a WEC to meet the materials needs rather than trying to design a material that meets existing WEC design needs." — Matthew Holland, Wave Energy Scotland

Matthew Holland discussed a variety of efforts at Wave Energy Scotland. Wave Energy Scotland has conducted landscaping projects aimed at characterizing the state of the wave energy sector and identifying areas for potential future funding and development. Through its three-stage Structural Materials and Manufacturing Programme, the agency funded 10 technology projects across four topic areas: hybrid, elastomer, concrete, and other solutions.

Two of the projects, Arup in the concrete area and Tension Technology International's inflatable bag design in the elastomer category, have moved to the third stage and are nearing their conclusion. Efforts on both projects have resulted in free, online design tools—CONVEX and NetBuoy—to support decision-making. Wave Energy Scotland has also researched inflatable dielectric elastomer generators for power take-off.

The top needs Wave Energy Scotland identified are further R&D into flexible, compliant materials; a better understanding of constraints on novel materials; and manufacturing supply chain development.

2.8 University of Maine, United States

Richard Kimball, Professor of Mechanical Engineering and Presidential Professor of Ocean Engineering and Energy

Summer Camire, Mechanical Engineering Graduate Research Assistant

> "Having the ability to manufacture large-scale molds could lead to the development of novel concrete technologies for WECs." —Summer Camire, University of Maine

Richard Kimball and Summer Camire presented the university's work in rapid prototyping and large-scale additive manufacturing for WECs. University of Maine is home to the world's largest 3D printer, an indoor wind-wave basin, and a full-scale ocean test site. The rapid prototyping will start with model testing in the wave basin. Then buoy data from the ocean test site will be used to design a unique wave environment to optimize and iterate on WEC prototypes. On the additive manufacturing side, the project will include fast development of novel materials using 3D-printed molds.

Based on past and present projects, the Maine team believes WPTO should focus R&D funding on additive manufacturing advances, concrete hull technology, and scaled ocean testing.

2.9 Oscilla Power, United States

Tim Mundon, Vice President, Engineering

> "Being able to use advanced design approaches allows us, enabled by advanced materials such as composites or plastics, to come up with new solutions...to keep weight down and meet the needs of operating in a corrosive and highly forced dynamic environment." —Tim Mundon, Oscilla

Tim Mundon introduced key findings from Oscilla's work across three projects related to its WEC devices. Oscilla's Triton WEC is a two-body point absorber with a float and a reaction ring that hangs beneath the float on three tendons. The tendons are prone to cumulative bending fatigue, which means it is extremely important to find materials suitable for bending. Other areas of the device where materials innovation could potentially improve performance include a composite hull and new materials for hydraulic seals.

The four materials project needs identified were concrete 3D printing to minimize underwater structure costs; development of plastics suitable for extended saltwater immersion with high strength and low friction; exploration of health monitoring solutions for ropes and tendons to predict residual lifetime; and open-source measurement and categorization of hydraulic piston seal performance and longevity.

3 Breakout Discussions and Conclusions

In Part II of the workshop, participants were separated into small breakout rooms for discussions within the three device topic areas: conventional WECs, CECs, and unconventional WECs. At the conclusion of the breakout sessions, representatives from each device area presented the key research needs and priorities identified.

Manufacturing supply chain issues, including factors such as scale, location, and availability of production capacity; sustained production opportunities; and accelerated prototype manufacture were considered critical long-term investments needed for all conventional WECs, CECs and unconventional WEC areas.

3.1 Conventional Wave Energy Converters

The general consensus for R&D needs in the WEC included additional materials research on hybrid and flexible materials/elastomers, as well as improvements in modeling confidence of these new materials. (This consensus applied to unconventional WECs as well; see below.) Supplementary R&D is needed in advanced manufacturing of WEC components and subcomponents. Other needs include additional test capability and supply chain improvements.

In the WEC *materials selection space*, there are some gaps that were acknowledged, particularly in the polymer, ceramics for bearings, coatings, sealing solutions, flexible materials, and concrete areas. Those areas should be addressed for fundamental R&D in the near term.

In the WEC *testing space*, strength and edge abrasion (particularly of ropes) and fatigue are areas that need additional work. Investigation of the recyclability of polymer-based materials should also be conducted. Corrosion, biofouling, true environmental conditions, and the need for sensors will continue to be addressed with respect to WEC devices. Again, the need for complementary test centers was acknowledged.

Modeling in the WEC space should focus on life cycle analysis, incorporating data from testing and possibly machine learning, and modeling composites, novel, and flexible materials.

In the WEC *manufacturing space*, composites manufacturing, automation, and additive manufacturing should be invested in to reduce device costs. As in the CEC space, the potential for leveraging from other industries was noted.

Additionally, there was a recommendation to add a materials and manufacturing component to both old and new awards to encourage partnerships and leverage funding pathways like the Verdant and ORPC development campaigns.

3.2 Current Energy Converters

The general consensus in the CEC space was that there was a parallel path currently required for device development. From a system level, there is a need to develop and characterize in open water to build confidently in performance and to understand what system topologies work best. To enable developers to quickly iterate the material, structural, and hydrodynamic aspects required for system codesign, research in the following areas is critical:

- Develop a better understanding of properties for different materials that can be used for both existing and emerging manufacturing methods
- Develop faster and more economical manufacturing processes.

More specifically, in the CEC *materials selection space*, gaps identified included further research on coatings, flexible materials, fiber sizing, adhesives, and joints, and additional data to better understand the performance and reliability of different materials, especially composites, metal and concrete for mooring, and novel nanomaterials for monitoring. These areas should be addressed for fundamental R&D in the near term. It was also noted that it is critical to leverage work in other industries like aerospace and maritime as well as research in other federal agencies (U.S. Navy, Advanced Manufacturing Office, etc.).

In the CEC *testing space,* strength, fatigue, and analysis of water permeating into composites are areas that need more work. Investigation into the recyclability of polymer-based materials should also be conducted. Corrosion, biofouling, true environmental conditions, and the need for sensors will continue to be addressed with respect to CEC devices. Generally, the need for more test capabilities and complementary test centers was acknowledged, which would provide synergies with existing centers to improve collaboration and ensure standard procedures/test protocols as well as accelerated testing.

Modeling in the CEC space should focus on strength, fatigue, loading, biofouling, corrosion, FSI, and life cycle analysis. The use of machine learning, high-performance computing, and FSI optimization were also noted as gaps in modeling.

In the CEC *manufacturing space*, additional research needs were identified in the area of composites and novel material manufacturing and automation to reduce device cost, as was research into improved cost-effective manufacturing options to accelerate and improve prototyping. The use of machine learning was also mentioned to improve component-level manufacturing.

3.3 Unconventional Wave Energy Converters

In the unconventional WEC *materials selection space*, some gaps were acknowledged, particularly in understanding the effects of using composites, polymer, adhesive, coatings, flexible materials, and concrete within these unique designs. Those areas should be addressed for fundamental R&D in the near term.

In the unconventional WEC *testing space,* strength and fatigue are areas that need more work. Investigation of the recyclability of polymer-based materials should also be conducted. Corrosion, biofouling, true environmental conditions, and the need for sensors will continue to be addressed with respect to unconventional WEC devices.

Modeling in the unconventional WEC space should focus on loading, life cycle analysis, and biofouling.

In the unconventional WEC *manufacturing space*, investments should focus on composites and additive manufacturing to reduce device cost.

Table 1 summarizes the identified needs for each device area.

Table 1. R&D Needs Identified

Area	WEC	CEC	Unconventional WEC
Materials selection	• Polymers • Ceramics for bearings • Coatings • Sealing solutions • Flexible materials • Concrete	• Coatings • Flexible materials • Composites/fiber sizing • Adhesives and joints • Novel nanomaterials for monitoring	• Composites • Polymers • Adhesives • Coatings • Flexible materials • Concrete
Testing	• Strength and edge abrasion (particularly of ropes) • Fatigue • Recyclability of polymer-based materials • Corrosion, biofouling, true environmental conditions • Sensor development • Complementary test centers	• Strength, fatigue, and analysis of water permeating composites • Recyclability of polymer-based materials • Corrosion, biofouling, true environmental conditions • Complementary test centers • Standard test protocols including accelerated testing	• Strength and fatigue • Corrosion, biofouling, true environmental conditions • Sensor development
Modeling	• Life cycle analysis • Composites • Strength/fatigue/loading	• Strength, fatigue, loading, biofouling, corrosion • FSI and life cycle analysis • Machine learning methods and high-performance computing	• Loading • Life cycle analysis • Biofouling
Manufacturing	• Advance manufacturing of components • Composites manufacturing • Automation • Additive manufacturing	• Faster and more economical manufacturing processes • Composites • Novel material manufacturing and automation • Machine learning for component-level manufacturing • Better understanding of properties for different materials	• Composites • Additive manufacturing
Other	• Add a materials and manufacturing requirement to new awards and consider providing resources to existing awards • Potential to leverage insights from other industries	• Improved cost-effective options to accelerate and improve prototyping • Potential to leverage insights from other industries	• Investigation into the recyclability of polymer-based materials

4 Next Steps

WPTO's Workshop on Materials & Manufacturing for Marine Energy Technologies provided a significant understanding of the gaps in research and opportunities for future R&D investment. This information, along with past R&D results and gaps already identified by national labs and international entities, will help WPTO define a solid and comprehensive strategy for its materials and manufacturing efforts to advance marine energy.

WPTO understands that its materials and manufacturing strategy is a work in progress that requires consistently evaluating the market to ensure the strategy complements and leverages current R&D efforts, including collaborating with federal partners (such as DOE, the Department of Defense, the Department of Transportation, and others) and with international partners, as well as continued engagement with our academic and industry partners. WPTO will continue to forge these relationships to ensure strong collaboration.

We appreciate stakeholder involvement in working with WPTO to enhance its strategy and maximize investment impact. **We encourage and welcome comments or further input regarding this document and the identification of new needs and gaps. All communications around WPTO's materials and manufacturing strategy can be directed to wptomaterials@ee.doe.gov.**

Appendix 1: Workshop Agenda

Tuesday, October 5, 2021, 10 a.m.–2:30 p.m. ET

10–10:30 a.m.	Welcome/Logistics
10:10–10:30 a.m.	Marine Energy Technologies: The Materials Landscape
10:30–11:20 a.m.	**Part I. Marine Energy Materials Project Presentations** University and industry partners will present their materials projects in major research areas, including wave energy converters (WECs), tidal/current energy converters (CECs), or unconventional WECs. (Presenter has 3–5 minutes to present and 5 minutes for Q&A.) Presenters: • University of Edinburgh • Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) • Verdant Power • Ocean Renewable Power Company (ORPC) • CalWave • Aquantis/Ecomerit
11:20–11:30 a.m.	Break
11:30 a.m.–12:20 p.m.	**Part I. Marine Energy Materials Project Presentations (continued)** Presenters: • Wave Energy Scotland • University of Maine • Oscilla Power
12:20–12:30 p.m.	Break
12:30–2 p.m.	**Part II. Breakout Discussions** Facilitators will lead group discussions to identify funding gaps and create a prioritized list of research and development (R&D) activities for future Water Power Technologies Office (WPTO) materials funding investments. All attendees will have the opportunity to provide feedback on the materials projects presented in Part I, share additional materials projects, and make suggestions on R&D funding priorities.
12:30–1:15 p.m.	Breakout Discussion 1: Wave Energy Converter Needs Breakout Discussion 2: Tidal and Current Energy Converter Needs (These breakout sessions will take place simultaneously. Attendees choose which session to join.)
1:15–1:25 p.m.	Break
1:25–2:10 p.m.	Breakout Discussion 3: Unconventional Wave Energy Converters and Other Needs
2:10–2:25 p.m.	**Part III: Report Out** Facilitators will present a prioritized list of materials R&D activities for each of the three device types for future WPTO funding investments.
2:25–2:30 p.m.	Closing

Appendix 2: Participating Organizations

Aimen Technology Centre

Akita Innovations

American Bureau of Shipping

Arkema

Aquantis/Ecomerit Technologies

CalWave Power Technologies

Circular Carbon Innovations

East Carolina University

Emergy

Engineering Industries eXcellence

European Marine Energy Center

E-Wave Technologies

Florida Atlantic University

General Electric

Greatly Observed Objectives Defined

GTA Renewable Energy

Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER)

Lehigh University

Lloyd's Register

Marine Renewable Energy Collaborative of New England

Montana State University

National Renewable Energy Laboratory

National Technical University of Athens

North Carolina State University

Oak Ridge National Laboratory

Ocean Energy

Ocean Power Technologies

Ocean Renewable Power Company

Oregon State University

Oscilla Power

Pacific Northwest National Laboratory

Resolute Marine Energy

Rockall Solutions

Sandia National Laboratories

Strategic Marketing Innovations

Stantec

Southern Company

Texas A&M University

TWB Environmental Research and Consulting

United Kingdom Health and Safety Executive Science and Research Centre

United States Bureau of Ocean Energy Management

United States Environmental Protection Agency

United States Geological Survey

University of Alaska

University of Colorado

University of Edinburgh

University of Hawaii

University of Illinois

University of Maine

University of North Carolina at Chapel Hill

University of the Philippines

University of Washington

Verdant Power

Virginia Tech

Wave Energy Scotland

West Atlantic Marine Energy Community

Woods Hole Oceanographic Institution

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