POSTION PAPER 2:

MARINE ENERGY PRIORITIES

National Hydropower Association Marine Energy Council
February 2023

I. Mission of the Industry Priorities Working Group

The mission of the Marine Energy Priorities Working Group (MEP WG) is to support the National Hydropower Association's (NHA) Marine Energy Council (NHA-MEC) in providing a common voice and platform regarding the needs of the Marine Energy industry in the U.S. The MEP WG will identify common priorities for technology and project developers across the range of Marine Energy resources and provide direct feedback to the MEC regarding technical areas in need of funding and/or clear gaps in knowledge. The MEP WG will maintain a broad range of industry stakeholders on the Working Group, as best possible.

II. Background & Motivation

The MEP WG of the NHA-MEC was established in early 2021 to identify and prioritize specific needs and knowledge gaps wherein federal R&D funds could be most effectively applied to advance the Marine Energy (ME) industry to commercialization as rapidly as possible. To date, the MEP WG has met monthly to debate the issues associated with industry priorities, and in September 2021, a poll was circulated that requested MEP WG members to identify and prioritize the needs and knowledge gaps that are most critical to the achievement of the sector's technology and project development goals. In July 2022 the MEP WG circulated a survey to developers and stakeholders in the MEC of which the results are shown in this paper.

The following report summarizes the methods the MEP WG used to obtain and analyze poll and the survey results by segregating the highly diversified ME stakeholders into distinct categories that include device size, Technology Readiness Level (TRL), commercial application and priority ranking. The purpose of this exercise was to determine how broadly the knowledge gaps applied across all categories, which can be used as a proxy for the 'criticality' of needs and specific knowledge gaps. This report is intended to be updated regularly based on additional input and natural changes in the industry priorities.

In summary, the object of this report is to communicate the most critical needs of the ME industry to a broad range of stakeholders and thereby recommend funding initiatives focused on research & development that will be the most effective in reducing the time to commercialization.

For the purposes of this document, the MEP WG has used the following scales for discussion:

1. Micro-scale: Marine Energy Converters (MEC) for powering isolated oceanographic instrumentation or similar Powering the Blue Economy (PBE) activities.
2. Meso-scale: MEC that could be installed individually to support a facility or community (may or may not be grid-connected).
3. Macro-scale: MECs that are intended to be installed in arrays to provide commodity power to a distribution network (i.e., grid-connected).

III. Target Audiences

At the start of the analysis, the MEP WG identified several audiences potentially benefiting from the position paper. In no particular order, those audiences include:

- **Industry and NHA-MEC.** The outcomes of this paper will be further utilized to develop a roadmap to widespread commercial applications for the marine energy sector. Eventually, the MEP WG will request input and feedback into the priorities set out in this position paper from NHA-MEC members.
- **Government funding agencies.** Outputs from this document will be utilized in preparing the Marine Energy Roadmap efforts led by the NHA-MEC. Based on information in this position paper, recommendations for government funding agencies will be presented.
- **Testing Expertise and Access for Marine Energy Research (TEAMER) and the University Marine Energy Research Community (UMERC).** These programs have a broad network of people and areas of expertise. The MEP WG and the information gathered in this position paper will be shared with both the TEAMER and UMERC groups. These groups will also provide the MEP WG with industry needs as they arise within their discussions.
- **International Electrotechnical Committee (IEC).** Standards at the Technical Committee 114 (TC 114) and certification at the IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications (IECRE - Renewable Energy). As standards are developed, they should be aligned with the priorities of the industry to accelerate commercialization of the ME industry.

The MEP WG does recognize that there are other potential audiences, not mentioned above, who may be interested in this document and will strive to include the audiences as they are identified.

IV. Methodology

The MEP WG first identified current needs and gaps within the industry. Once the straw-man list was created, the group reevaluated the list and eliminated or grouped 'like' ideas. The reevaluation of the list took place in three successive steps. A list of 22 subject line items relevant to all marine energy was developed. This list was then placed within a survey for ranking of each item by priority of high, medium, or low. The survey also requested that participants assign an associated development scale – ***micro*** (ocean observation/PBE), ***meso*** (small communities) or ***macro*** (utility). The survey was sent to the MEP WG participants and marine energy developers and stakeholders on August 31st, 2021 and was completed on September 9th, 2021. The results of the survey are shown in Figure 1 and Table 1. Additionally some interesting and valuable comments were made by Marine energy developers and stakeholders which are listed below Table 1.

V. Industry Priorities

The figure below shows the priorities broken into higher, medium, and lower based on the survey responses. Under each priority heading, the priorities are presented in no particular order and do not yet fully map to the associated TRL and development scales.

HIGH PRIORITIES	MEDIUM PRIORITIES	LOW PRIORITIES
Funding for development and testing of ME devices	Non-electrical applications: direct desalination	Technology Qualification at earlier TRL
Export cables; Anchoring; Mooring	Power aggregation of multiple MEC	Array testing facilities of late TRL
Continued support of process that will retire environmental risk	Personnel/electrical safety	Hybrid systems in early TRL
Controls/Power Take-off optimization	Circular economy	Data Issues late TRL
Installation, Operation, Maintenance and Decommissioning	Advanced materials development thermoplastics and composites etc.	
Standards supported development suitable for utility-scale market	Alternative power carriers to eliminate the export cable	
Health monitoring of dynamic elements / predictive maintenance	Basic Research	
Manufacturing including Additive/Subtractive Manufacturing	Workforce development	
Streamlining the regulatory process		
Robust Federal staffing		

Figure 1. Generalized Industry Priorities

Specific comments from Marine Energy Device Developers:

- The main problem for all developers is still the lack of substantial, steady flow of federal funding for sustained development, mainly to bridge the Valley of death TRL 4 to TRL 7. This would really advance technology and facilitate deployment of Marine Energy Converters. Co-Development with offshore wind and solar. Hydrogen and Hydrogen derivatives as a substitute for the "magic cable" economic analysis and study of integration of same.
- Increased support for an overall larger marine energy program equal to the scale of the opportunity.
- Priority 5 comes automatically with 1 for in-water testing; seems redundant to ask because IO&M can't occur without funded testing. Priority 3 is similar for risk retirement. That only happens with in-water testing. I don't understand what Priorities 11,14 and 22 are asking about.

VI. Discussion

The MEP WG acknowledges that industry priorities differ based on the end-use or target market of a device or project development. One essential finding that remains true for all stages of development within marine energy is the need for increased funding in the form of Federal Funding Opportunities Announcements (FOA) or other financial investments for the sector to reach commercialization. These federal funding opportunities are necessary for developers to reach commercial readiness. The reliability for such funding is also important as it is critical to have both higher frequency and greater certainty of dedicated resources for component and device research, development, and demonstration (RD&D).

Currently, FOAs are important to support the middle portion of a development project, the so-called TRL 4-7 'Valley of Death'. Most developers have sufficient funding to finance the startup of a project. Once a device reaches a TRL 7, developers can typically raise capital from the private sector that is willing to invest in these technologies with ROI in the near future and take them to commercial manufacturing. However, the middle portion of development is perhaps the most important to have financing available for development and testing in the form of FOAs and testing schemes, such as the TEAMER program.

As mentioned in the methodology section, the MEP WG had participants assign a development scale to a priority. It could be equally important for priorities to be examined at the system TRL versus the target development level. Priorities important to a TRL 1-3 technology that is aiming for a PBE end use, may not be as critical to a TRL 1-3 technology with an end use of a grid-connected, utility scale array. Therefore, breaking down individual needs into specific development and system size categories may benefit the ability to prioritize the needs of the industry. The priorities that are most impacted across the TRL levels will yield the highest-level priorities.

In the table below, each unique priority line item is assigned a letter and a number two reflect the combined results of the survey answered by MEC members, industry developers and stakeholders. The path to higher TRL, and the associated priorities along that path, are unique for each project or technology developer. However, since most development projects or technologies start at a small scale and evolve to a medium scale before they end up qualifying for large scale production, the group determined the focus should be Field A, E, and I (indicated in red as a higher priority). The groups A, E and I are also the groups that required the most funding in that critical stage. The MEP WG was then able to further identify the main challenges of development at each stage.

A more complete mapping of the industry priorities in Figure 1 to the categories in Table 1 is an outstanding exercise for the MEP WG to conduct during the next document revision cycle, based on additional input from an NHA-MEC membership-wide survey to be conducted in 2023. Initial results suggest that most of the higher priorities are relevant at multiple development scales while other priorities are clearly mapped to TRL and/or development scale.

TRL/Target system size	Micro (Ocean Obs/PBE)	Meso (Island/Community)	Macro (Utility, grid-connected)
1 – 3	A	B	C
4 – 6	D	E	F
7 – 9	G	H	I

Colors: HIGHER PRIORITY; MEDIUM PRIORITY; LOWER PRIORITY.

Table 1. System to enable mapping of Industry Priorities to TRL and Development/System Size.

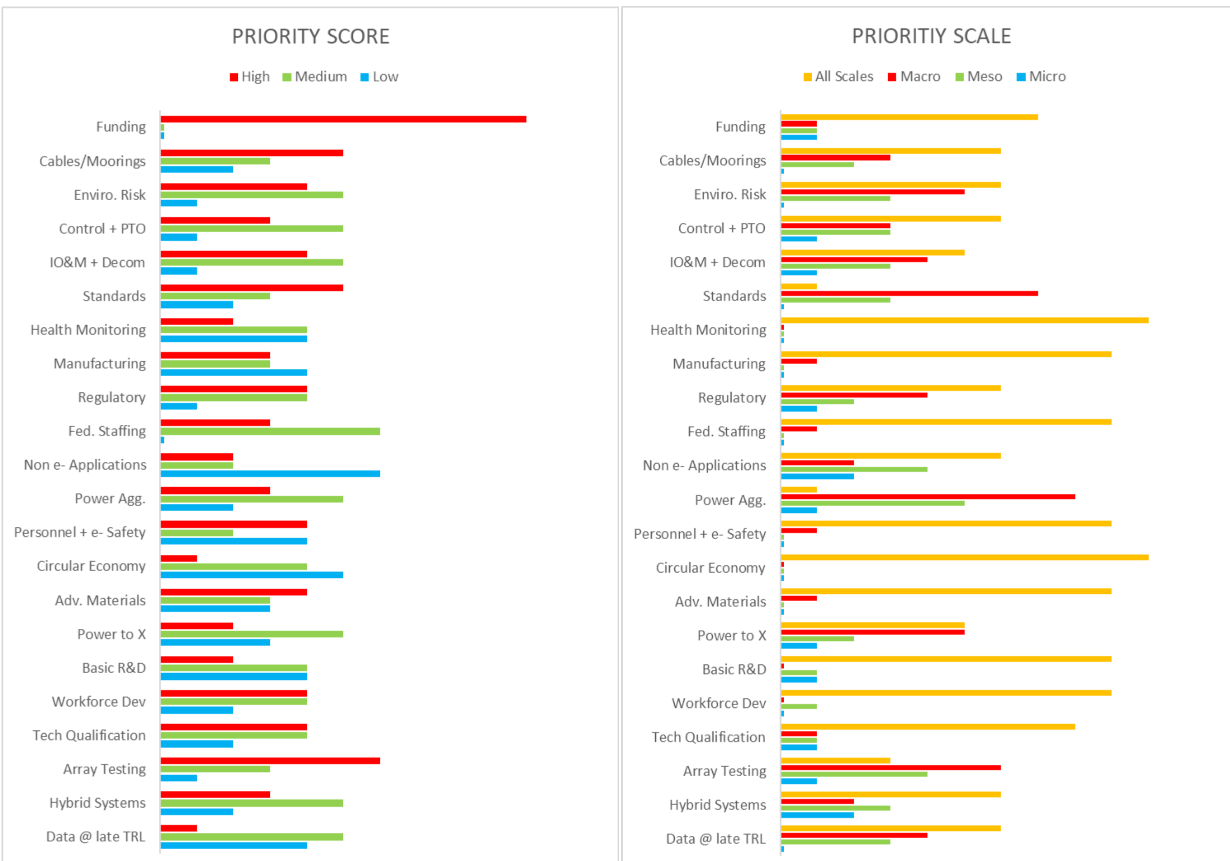

Table 2. Results of MEC Survey on Priorities of Importance and on which Scale

All target audiences of this poll and the survey MEP WG has conducted should note that there is clearly an expressed need for component and subsystem R&D funding.

Another issue identified revolves around the resources type within the ME sector, the priorities are likely to differ between wave technologies and current technologies. The MEP WG aimed to identify common challenges and overlap between the different technologies when developing the list. For instance, export, anchoring, and mooring are cross-cutting components that are a higher priority for both wave and current technologies. Another example focuses on prioritizing challenges with Installation, Operations, Maintenance and Decommissioning IOM&D, which covers both wave and current technologies. Decreasing the time and cost of IOM&D by developing best practices and levering best practices from other relevant sectors such as floating offshore wind could help accelerate the industry to commercialization.

It is the NHA-MEC's MEP WG's position that the DoE's focus on smaller size devices and PBE is valuable as a mechanism to increase interest in this field, and spur investment. However, this market in and of itself is not sufficient to support the long-term potential of this industry or to take full advantage of the marine energy resource. Effort must continue to be focused on using this approach as a route to the adoption of larger, grid-tied marine energy projects, and not only as an industry in and of itself. Nonetheless, smaller devices will also have a place in the market for installation in a variety of setting, such as aquaculture facilities, as well as remote micro-grids, underserved off-grid communities and native lands and even grid connected end-users in coastal communities where tidal flow or riverine flow is available. These aforementioned locations oftentimes rely on diesel generators to produce electricity which results in an extremely high LCOE. This is an area where current devices at Meso scale under development can have the biggest impact.

Comparison with Commercialization Strategy

In 2021, NHA's Marine Energy Council issued the 'Commercialization Strategy for Marine Energy,' which outlined 10 federal actions needed to meet the 50 MW by 2025, 500MW by 2030 and 1GW by 2035 targets. This section provides a comparison of those needed federal actions, identified in Commercialization Strategy and the industry priorities identified through the MEP WG.

The list below highlights the necessary federal actions outlined in the Commercialization Strategy and how they align with the industry priorities:

1. System Design, Fabrication and Demonstration –captured as several higher priority items.
2. Fostering Distributed Generation Capabilities – captured as several higher and medium priorities.
3. Emerging Opportunities for Off-Grid Power – captured as higher and medium priorities.
4. Foundational Research and Engineering Assistance –captured as a medium priority.
5. Testing Infrastructure and Validation – captured as a medium priority. See additional information regarding TEAMER below.
6. Financial Incentives for Deployment – captured as a higher priority.
7. Leveraging International Experience and Standards – captured as a higher priority.
8. Streamlining Permitting and Reducing Regulatory Barriers – captured as a higher priority.
9. Workforce Development – captured as a medium priority.
10. Federal Planning, Staffing and Industry Engagement – captured as a higher priority.

We can see that the industry priorities align well with the Commercialization Strategy federal action requirements, however, there are some priorities not captured in the Commercialization Strategy that are (or will) be necessary for the industry to be successful.

It is also noted that some of the priorities are currently being funded through programs like TEAMER and UMERC, which is discussed further.

Integration with UMERC and TEAMER

As can be seen in the priorities list, development and testing for the industry sector is a higher priority and basic research is a medium priority, with some opinions that basic research is always a priority. It is evident that the Department of Energy's Water Power Technologies Program (WPTO) recognized the gaps in testing and basic research. While these programs may not address the entire testing and basic research needs, they do present a step in the right direction.

The Testing Expertise and Access for Marine Energy Research (TEAMER) program, coordinated by the Pacific Ocean Energy Trust (POET), provides funding support for marine energy system developers to test their systems at facilities around the U.S. The facility network consists of national labs, university and private-industry facilities with expertise and capabilities from numerical modeling, bench testing, and tank, basin, flume, and tunnel testing. TEAMER also has added select open-water facilities to the network. While the PacWave and WETS test sites will address higher-TRL, larger scale testing, significant gaps remain for current energy converter testing at, or near, full-scale.

TEAMER allows for marine energy system developers to access testing that may otherwise be cost prohibitive, allowing for a more iterative design process. Developers can test whole systems or components. This organization has been enormously beneficial to the industry so far and must continue to be funded far into the future.

The WPTO awarded funding to POET in Aug 2021 as the coordinator of the University Marine Energy Research Community (UMERC). The aim of this program is to facilitate communication between university researchers, labs, and industry to ensure that industry research needs are being met, while also identifying existing capabilities of researchers. This should create more alignment between research stakeholders and make sure that short, medium, and long-term research needs are met.

UMERC is working on a research landscape to get an understanding of what research is currently taking place and how we can link those common themes with the priorities identified in this white paper. UMERC will use this information to help facilitate workshops and seminars, as well as an annual summit in an aim to share information to a broad audience.

More information on funding and activities at open-water WEC test sites PacWave and WETS is available online via numerous sources.

VII. Key Recommendations

- Increased federal funding
- Increased number of FOAs and in predictable increments
- Data sharing
- Knowledge/Lessons Learned sharing
- Stage-gated funding for small systems and from sub-scale system up to large system development
- Ensure funding for concurrent robust supply chain and manufacturing development
- Clarity of different requirements for different sectors

Appendix A (Industry Priorities Organized by Technical Content, Not R&D Priority)

- Export cables
- Anchoring / Mooring
- Mooring (applying existing knowledge / knowledge transfer / non-IP specific solutions)
  - Anchor Sharing
- Mooring/electrical/hydraulic connections (quick connection and combined)
  - Both dry-connect and wet-connect
- Smaller capacity electrical cables
  - Development of much lower cost export cable installation approaches for community-scale systems.
  - Cable handling (data / power) - (large dynamic cables)
  - Cost-effective wet-mate connectors. Remote operation.
- PTO
  - Direct-drive turbines
  - Scalable gearboxes
  - Scalable power electronics
  - Magnetic gearboxes
- Power aggregation of multiple MEC (arrays)
- Power quality for utility scale and community scale (e.g., microgrid applications)
- Grid integration for utility scale and microgrid integration for community scale
- Manufacturing: including Additive/Subtractive Manufacturing (3D printing of concrete, polymers: i.e., fiber reinforced thermoplastics for example)
- QA/QC/QMS
  - Product Lifecycle Management (PLM) tools
  - Document/Drawing control
- Lack of experience and knowledge on installation
  - Knowledge transfer
    - New database/portal vs. existing resources (PRIMRE, NHA OpEx, etc.)
    - Installation specific MHKDR inputs
    - Workshop/Forum format vs. database/excel spreadsheet format
  - Multi-use vessel?
- Installation Guidelines / Standards
  - Common installation methodologies
- IOM&D Challenges
  - Staff training / STEM initiatives
  - Develop best practices - Avoid overly conservative O&G procedures/standards
  - AUV/ROV remote maintenance - reducing staff maintenance/increasing safety
  - Remote monitoring
  - Activities in extreme conditions - Minimizing time onboard. Avoiding
  - Cost estimation tools
- Technology Qualification at earlier TRL (using IEC standards)

- Standards supported and based development of MEC's suitable for the utility-scale market.
    - Deployments at PACWAVE - technology gated
    - PACWAVE is still relevant.
- Advanced materials development (seems broad) specifics
    - Corrosion resistance
    - Mass reduction
    - Friction/Abrasion resistance (fairleads, etc.)
    - Coatings for biofouling
    - Thermoplastic composite materials (circular economy consideration)
- Health monitoring of dynamic elements (electrical cables, ropes, blades, gearbox, etc.)
    - Predictive Maintenance
    - Use of digital twin
- Controls/Power Take-off optimization
- Alternative power carriers (storage vectors) to eliminate the export cable and open new export markets. The ability to produce a commodity offshore as an alternative to electricity (hydrogen, ammonia, etc.) to eliminate the export cable.
    - Need partners - not developer core IP
    - Wireless power transfer, this technology is already being employed
- Non-electrical applications, including direct desalination
    - Direct drive for pumping fluids (aquaculture, agriculture)
- Hybrid Systems
    - Offshore wind/Wave/Current
    - Floating solar/Wave/Current
- Basic Research
    - Hydrodynamic performance
    - Wake modeling (aka array dynamics)
    - Computational Fluid Dynamics (CFD) simulation, analysis, digital optimization
    - Erosion/Scour/Sediment transport
- Data:
    - Acquisition/management
    - Common analysis techniques
    - Utilize/Interface with: AI, Big Data, Cloud, etc.
    - creating digital twins for ease of maintenance, repair, and monitoring
- Array Testing Facilities
- Safety
    - Personnel/Electrical safety
- Continued support of processes that will ultimately retire environmental risk and streamline the regulatory process. While continuing to respect the positive environmental change that MEC can provide.
- Circular Economy
    - Recyclability vs. landfill
    - Non-toxic lubricants
    - Rare-earth elements

- Product life-cycle assessment (access to, and training in, software tools)

Appendix B (Feedback from Building the U.S. Marine Energy Roadmap Strategy Summit, October 19, 2021)

Are the top priorities the right ones? Are there others that are missing from this list? (Refer to the Marine Energy Priorities Working Group Presentation)

Comments:

- **General Comments**:
  - Priorities should be mapped to Commercialization Strategy initiatives for consistency in messaging.
  - Priorities should be identified by resource to account for differing concerns.
  - We need to understand the requirements of marine energy end-users. Why would they buy it? Why do they need it?
- **Suggested Additions to Priorities**: (Grouped in accordance with the Commercialization Strategy)
  - 1. System Design, Fabrication, and Demonstration:
    - Consider placing manufacturing higher on the priority list – need to look at the design for manufacturing in order to achieve cost numbers. Increased involvement by SMEs is needed. (Benefit of TEAMER, larger scale manufacturing to provide feedback to people before they go too far down the road.)
    - Supply Chain: Supply chain development (may need to assess, as every company builds its own chain as it progresses)
  - 2. Fostering Distributed Generation Capabilities:
    - Power aggregation linking with offshore wind
    - Leverage infrastructure with offshore wind
  - 4. Foundational Research and Engineering Assistance:
    - Development of marine energy-specific lifecycle assessment processes for overall carbon footprint. Net impact from an environmental point of view. Greenhouse gas emission reductions. Develop a GHG calculator.
  - 5. Testing Infrastructure and Validation Support:
    - Testing facilities for wave are a lower priority because of the developments at PacWave and WETS. This is not the case for current devices (current used as an all-inclusive term) and has been identified as a gap. In fact, coupled with the previous item current developers face double the challenges.
  - 7. Leveraging International Experience and Standards:
    - Standards should be considered a higher priority within PBE
    - Increased adherence with international standards, will likely contribute to increased competitiveness with other countries
    - Consider a standard for techno-economic assessment of specific sites
    - Subsea cable standards
  - 8. Streamlining Permitting and Reducing Regulatory Barriers Environmental Risk:
    - Reduce/Retire environmental risk

    - Relieving the regulatory burden for smaller (sub-1, 3 or 5 MW) projects should be included. (Consider as one of the MEC's top priorities)
- 9. Workforce Development:
    - Workforce development & diversity
- 10. Federal Planning, Staffing and Industry Engagement:
    - Find and leverage beneficial partnership. For example, BOEM is a champion for offshore wind, and it is a lease holder. It is well positioned to be a cheerleader.

<u>Other Commentary</u>

- End user engagement (consider a company-by-company business development effort, the MEC can facilitate information exchange)
- Hybrid systems (Multiple federal actions impacted)

Questions To Consider:

- Should the marine energy sector engage with offshore wind for component co-development?
- Why is manufacturing so low given commercialization stage? Is this industry-wide or resource specific?

Appendix C (MEP WG Participants as of March 2023)

Bruce Bauchmire, DLZ, Member
Jonathan Colby, Streamwise Development, LLC, Co-Leader
Paul Gay, SMI, Member
Shana Hirsch, Pacific Marine Energy Center (PMEC), Member
David Hoyle, Tide Mill Institute, Member
Chris Lee, Tidal Energy Corporation, Member
Reenst Lesemann, Columbia Power Technologies (C-Power), Member
Tim Mundon, Oscilla Power, Inc., Member
Balky Nair, Oscilla Power Inc, Member
Dan Petcovic, CalWave Power Technologies, Inc., Member
Samantha Quinn, Pacific Ocean Energy Trust (POET), Member
Kelly Rogers, National Hydropower Association (NHA), Staff
Walter Schurtenberger, Hydrokinetic Energy Corp., Co-Leader
Bill Staby, Resolute Marine Energy, Member
Wes Williams, UNC Charlotte, Member

Appendix D (Technology Readiness Level Definition)