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U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Wind and Water Power Technology Office

Subject: Request for Information: Program Strategy to Advance Marine and Hydrokinetics

Submitted via electronic mail to: MHKRFI@ee.doe.gov

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As the national trade association for all water power technologies, the National Hydropower Association represents all types and stages of marine energy technology, including wave, current (tidal, ocean, and river), and OTEC and through its Marine Energy Council. The Council appreciates the opportunity to respond to the Department of Energy's recent RFI, and to provide the industry's perspectives and insights about the development of these promising new technologies. We would like to emphasize that while certain of the RFI questions can be answered clearly and directly, other questions raise many issues that need clarification before a definitive answer can be provided. We have indicated the questions that require additional clarification, and we would very much appreciate the opportunity to follow up with the Program on these questions.

CATEGORY 1: Technology Advancement and Demonstration

1. *Investment Selectivity -- Is there value to be gained from Program investments in demonstration of technologies that have just a few of the required attributes? Please explain the relevance of any such investments to advancing the sector.*

We assume that the RFI is referring specifically to the integration of Technology Performance Levels (TPL) into the Program's decision-making process. While there is general agreement across our membership that Technology Readiness Level is an insufficient measure of commercial viability, and that integration of TPLs into the Program's decision-making process makes sense, more clarification on the methodology and its implementation is required before we can answer this specific question.

A non-exhaustive sample of our clarification questions follows:

1. What does “demonstration” refer to? For example, for wave energy converters, this could involve: Open-water testing of 1:1 (or 1:2) scale systems, fetch-limited site testing of 1:4 scale systems, fetch-limited site or laboratory testing of 1:15 scale systems or sub-systems, or laboratory testing of even smaller scale systems or sub-systems.
2. Does the Program intend to fund (low TRL) advancement of system concepts from low to medium to high TPL (other than through the Wave Energy Prize)?
3. The question implies that a technology must achieve scores above a threshold level for ALL of the TPL sub-criterion to qualify for Program investments in “demonstration”. Is this correct? Or does the synthesized TPL score just need to be above a certain threshold?
4. Is it the Program’s intention to use ACCW/CCE metric outlined in the Wave Energy Prize rules as a proxy for cost in the TPL evaluation? If so, how? Will this replace the [0.7 TPLCapEx + 0.3 TPLOpEx] term? If not, how does the Program intend to deal with uncertainty in cost estimates at early TRLs?
5. ACCW/CCE appears to altogether disregard device/generator conversion efficiency (electric power generated/absorbed power of the device). Is this correct? If so, doesn’t this have significant potential to lead to sub-optimal decisions?
6. How and when will TPL evaluations be carried out? Will the results be shared with the developers? Will there be opportunities for dialogue between the evaluators and developers during the evaluation process?

CATEGORY 2: Testing Infrastructure and Instrumentation

1. What unique capabilities or attributes should the program consider in the development of a full scale, grid connected wave test site in the U.S.?

The Northwest National Marine Renewable Energy Center (NNMREC) has conducted industry surveys regarding precise needs for a full-scale grid connected test facility. A test site for higher TRL technologies should have the following characteristics.

- The site should have energy resources similar to the fully energetic sites expected for commercial deployment.
- The site should be fully permitted so as to avoid lengthy and costly delays in deployment. No site will provide a “permit-free” experience for developers; however, every effort should be made to reduce the number and expense of any additionally required permits or studies.
- The facility should provide a means by which each developer can isolate its technology and measure directly how the device functions, especially in terms of electrical output and its interaction with the grid.

- Allowance should be made to support arrays of similar technologies, so that companies can better understand array effects on the technology and the environment.
- The testing facility should have access to established and respected environmental scientists to ensure that key questions are asked and answered on behalf of not just the one technology, but on behalf of the industry at large.
- Consideration should be made for supporting supply chain industries necessary to successful deployment, operation, maintenance and decommissioning.
- The facility should provide a range of durations available to developers, from short term (less than a year) to multi-year deployments.

2. What other test facilities may be needed and in what timeframe?

For current energy systems, major development and testing facilities are established at the European Marine Energy Center (EMEC), the UK National Renewable Energy Center (Narec) Catapult, and Nova Scotia Canada's Fundy Ocean Research Center for Energy (FORCE). In the U.S., there are opportunities for testing current energy converters with rated capacities up to 100 kW. It would likely be more cost-effective for DOE to either support US developer access to these facilities or convert an existing demonstration site into a test facility than begin development of a new test facility.

For current energy systems, in-water deployments that can verify power performance with precise water flow measurements, foundation designs and strategies, reliability, and operations and maintenance (O&M) strategies are essential for being able to deliver commercial projects. DOE should work with industry to identify and appropriately instrument potential demonstration sites that will allow U.S. water current technologies to achieve commercial status within the next 3-5 years.

For wave energy systems, it is possible that a test facility for shallow- to mid-depth devices would be useful. A market analysis should be performed to ascertain the need. The site identified in the Oregon Territorial Sea Plan in Warrenton, Oregon at Camp Rilea would be an example of an ideal location, if such a facility is needed.

CATEGORY 3: Environmental Research and Risk Mitigation

1. In years past the Program has provided support for targeted environmental research in lab settings (e.g., flume studies to evaluate the safety of fish passing through current energy converters), for targeted environmental monitoring MHK devices in the field to help inform relative levels of risk, and for the collection and synthesis of environmental monitoring data from around the world. From your perspective, which of these efforts has been most helpful in *reducing your barriers to deployment? What environmental questions do you think have greatest need for DOE support moving forward and why?*

Flume studies documenting de minimus mortality of fish exposed to hydrokinetic turbines has proven useful, as has collection and synthesis of environmental monitoring data from around the world. Acquisition of baseline environmental data is a critical need. Useful baseline data is needed over large temporal and spatial scales. Suitable information cannot be acquired in the context of permitting and licensing studies by private sector applicants. Furthermore, the information is relevant to multiple mandates held by federal agencies; thus, there is a federal role in collection and dissemination of this baseline environmental information.

2. Recently, the Program awarded projects to develop and improve environmental monitoring instrumentation, informed in part by an experts' workshop that identified critical needs in this area (see: https://eere-exchange.energy.gov/#FoaId7b557d4f-c41d-4f1c-8183-79d792123dc5 and http://www1.eere.energy.gov/water/pdfs/monitoring_marine_converters.pdf). Is the advancement of environmental monitoring tools to reduce cost and increase monitoring capabilities a useful direction to focus future efforts and resources in coming years?

Near term DOE emphasis should be placed on: (1) identifying those information requirements that the federal government should address, (2) reviewing past and ongoing licensing activities to identify key issues, generalizable results, and critical information needs, and (3) identifying best practices for scoping essential studies required of license applicants.

CATEGORY 4: Resource Characterization

1. *Additional Resource Assessments -- If the Program were to conduct additional research in this area, what information should be captured and for which resources?*

Taking resource assessment to mean the study of the recoverable resource (theoretical, technical, or practical) from a region (ocean, river, or estuary) and resource characterization to mean the study of the aspects of the resource needed to define LCOE for a specific project within that region, then it would be helpful for the Program to better define uncertainties for the first-generation assessments, particularly given that the National Research Council (NRC) review of these assessments notes, "The resource assessments lacked coordination and consistency in terms of methodology, validation, and deliverable products," and that, "all five MHK resource assessments lack sufficient quantification of their uncertainties." This lack of consistency and unquantified uncertainty makes direct comparisons between practically recoverable resources difficult. As per the NRC recommendations, further, site-specific assessments of the practical resource, using models that explicitly account for feedback effects from large-scale extraction at locations of industry interest would help to quantify the uncertainty in the first-generation assessments.

The first-generation DOE resource assessments indicate that the aggregate potential of tidal, ocean, and river currents is significant and the technology to harness tidal, river, and ocean resources is fundamentally similar (some developers operate in all three spaces). These resources also have high predictability and the persistence of river and ocean currents allows them to offset traditional base load power generation without energy storage.

The MEC recommends that DOE begin developing second-generation resource assessments for both waves and currents that reduce the unquantified uncertainties in the first-generation assessments and begin to address concerns about practical resource comparisons raised by the NRC review of the first-generation assessments. These assessments could build on existing efforts by DOE and NREL to characterize early-market marine renewable energy sites.

2. *MHK "hotspots" -- What/where are the industry priority "hotspots" for more specific resource characterization?*

Marine renewables are on the cusp of commercial viability in distributed settings where power is expensive (e.g., remote communities and industrial facilities, military facilities, aquaculture, desalination, offshore platforms, islands and urban centers with high power costs). These are distributed applications with broad potential for U.S. developers and represent near-term payoffs for private sector investment. Technologies that harness various marine energy resources have shown promise in this area, with current technologies closest to commercial viability in these markets. "Hotspot" analysis should focus on those sites where marine energy resources are substantial and there are strong market pull mechanisms, either through high existing power costs or public support mechanisms.

3. *Challenges -- What are the biggest challenges to the MHK industry regarding resource assessment and characterization in the near term? 2-3 years? And beyond?*

In regard to resource assessment, the undocumented range of uncertainty in practical resource assessments for the U.S. are contributing to private investment challenges. "Single number" resource assessments imply a higher level of certainty than supported by the underlying models/methods. For example, the first-generation tidal current resource assessment did not directly simulate energy extraction, but relied on an approximate analytical relation to calculate the theoretical resource from natural quantities, such as flow rate and elevation, averaged across the "inlet" to a water body. If the first-generation resource assessments are taken as the final word in U.S. practical resource potential, this will significantly limit the willingness of private investors to support the development of current-related technologies in the U.S.

In regard to resource characterization, methods and technologies are available to characterize the MHK resource at all necessary time and space scales, but not cost-effectively. This limits the flexibility of developers to site projects. For example, if a developer characterizes the MHK resource at a particular location, but then, through subsequent actions, determines that the site is less ideal for other reasons (e.g., seabed geology, social conflict) the substantial investment in characterizing a specific site for WEC or CEC design raises financial barriers to shifting project locations.

4. *Next Steps -- In this regard, what will the next steps be to reduce the risk of offshore deployment of MHK devices and thus lower the costs of investing in the industry (e.g. new and cheaper technologies for measuring the resource, types of resource observations that will be required, time and spatial scales needed forecasting the resource, etc.)?*

The development of a lower-cost, medium-fidelity approach to resource characterization, through measurement, would provide additional siting flexibility and reduce industry costs for site exploration. The industry experience with numerical models is that underlying information (e.g., bathymetry, model forcing) is not sufficient to guarantee sufficiently accurate results for design load calculations, and, in some cases, annual energy production, even when the fundamental fidelity of the model is high.

5. *State-of-the-Art -- The Program is collecting information on the present state of the art for wave, tidal, river and ocean current resource characterization/assessment models and tools.*

a. What type of hardware and software are typical for MHK resource characterization and assessments?

In general, resource characterization typically requires measurements (hardware) and resource assessment requires modeling (software). At the scale of large (e.g., 100 MW) arrays, modeling of resource characteristics would be required to fill in the gaps for sparse measurements, but based on the experience with wind project financing, entirely model-driven resource characterization is unlikely to be viable.

The tools for resource characterization are increasingly well established and available (e.g., directional wave buoys, wave radars, acoustic Doppler profilers and velocimeters). By their nature, resource assessments tend to be customized to the particular body of water being studied, with the group conducting the assessment using the modeling tool with which they are most familiar. These software packages (e.g., SWAN, FVCOM) are increasingly capable of representing arrays of wave and current converters, allowing for feedback effects to be represented in simulation.

b. What items would be necessary to observe and at what levels and what time scales?

Ideally, resource characteristics throughout the water column should be resolved to the highest feasible resolution, up to a fraction of a second and a fraction of a meter over extended areas and periods. While such resolution will not always be possible, every effort should be made to acquire the best possible resolution.

c. Do these methods and technologies accurately characterize the MHK resource? If not, how can they be refined?

See response to Question 3.

CATEGORY 5: Crosscutting / Out of the Box Feedback / Other

1. *What are proper metrics for measuring industry progress at its current level of maturity?*

One standard measure of technology progress toward commercial maturity is Technology Readiness Levels (TRLs). TRLs provide a poor measure for industry progress toward commercialization because they do not incorporate technology advancements through new developments. New developments in a technology reduce the TRL level when in fact the technology, by incorporating lessons learned and new knowledge, has advanced toward commercialization, not receded.

At its current level of maturity the metrics should include in-water deployments, in-water power and reliability performance, DOE lab component and system tests and results, and demonstrated efficiency in on-water operations, and in system operations and maintenance.

Our view is that the objective for the marine energy industry is technology commercialization and commercial expansion. Appropriate metrics toward accomplishing this objective include industry standards developments, systems deployed and system power and reliability performance, independent verification, insurability, technology consortia and partnerships, and technology and the ability to finance projects.

2. *What are the biggest challenges that you face as an organization?*

A technology developer perspective: By far the largest challenge as a pre-commercial marine energy technology development company is continually attracting private investment throughout the decade plus lifecycle of energy technology development and commercialization. As a result, this challenge has affected the pace of technology development in the sector over the past decade.

Inconsistent and insufficient Program funding levels result in difficulties in developing and maintaining a robust and consistent engineering and technology staff and capability to address the wide range of engineering and technology challenges in commercializing marine energy technology. Related challenges resulting from uncertain funding and pacing of work activities include: building and maintaining a strong supply chain, retaining third-party verification consultants, initiating high-cost technology development and test regimes, and developing a commercial project pipeline. Appropriate federal support, providing risk mitigation, is the key to attracting private capital.

3. What are the largest cost drivers influencing techno-economic feasibility of MHK devices?

We have great confidence that MHK system and component costs are manageable and will be competitive at scale. Developments in materials and componentry for both wave and current systems will allow these systems to be manufactured, assembled and integrated and to eventually become cost-competitive. We are also confident that system performance levels will rise to deliver the high water-to-wire performance efficiency required for cost-competitiveness.

The major cost drivers that will determine the commercialization of these systems are those associated with the water resource, on-water operations, and achieving 20-30 year project lifecycle requirements within acceptable operations and maintenance cost limits. In terms of technology characteristics, these include underwater system reliability and longevity, and O&M service intervals. Since the technologies are pre-commercial, there has been little work to date on developing and optimizing on-water deployment/installation and retrieval equipment and strategies, for delivering optimal foundations for a range of sea bottom profiles, for long-term projects, and for O&M efficiencies. Basic to the project cost-effectiveness for all of these systems is the accurate measurement and characterization of the overall water resource at the site for cost-effective project design, system placements and deployments.

4. *What are the highest need research areas for the MHK industry?*

We believe that research should appropriately target two goals: (1) the identification, concept maturation, and early TRL (1-5) validation of high TPL technologies and (2) the demonstration (TRL 6-8) of reliable near full- and full-scale devices (including those with a medium TPL).

There is general agreement among our members that further work on environmental monitoring, risk mitigation, and open source design tools should be deprioritized for the near term in favor of the above.

With federal support, demonstrations in early-adopter markets can lead to transformative reductions in LCOE. Commercialization in early-adopter, distributed applications is not the ultimate objective of most developers, nor can it be the ultimate objective of federal support. However, such applications can be a stepping-stone to reducing LCOE (technology and "soft costs"). Demonstrations in distributed commercial markets will provide important opportunities for learning and advance technology towards viable utility-scale deployment in grid-connected markets. For example, solar PV initially developed in niche applications (e.g., space craft and satellites), grew into distributed markets (e.g., commercial roof tops), and matured into multi-MW commercial plants. Commercial demonstrations also provide industry with critical practical experience and the insight to recognize the potential impact of transformative technologies. The cost of demonstrating transformative technologies at commercially viable scale in these applications is generally lower than at utility-scale, both in terms of absolute cost and the political/social profile of failures.

Such early stage commercial demonstration support, perhaps modeled after the successful DOE Turbine Verification Program (TVP), would reap many benefits. Because the TVP implementation occurred when the wind industry was more mature than the marine renewables industry is today, this would require a few important adjustments to the program phase structure. For example:

- Phase 1: Support for demonstration of transformative technologies at test sites, such as what will soon occur at WETS.
- Phase 2: Support for demonstration of technology innovation for grid-tied markets in distributed settings (this has similarities to "Phase 3" of the TVP). DOE support could be commensurate to the level of innovation/risk being taken by the project developer. These demonstrations are an opportunity for companies to showcase their technology in cost-competitive applications, to build their supply chains and to show initial commercial revenue streams.
- Phase 3: Support for demonstration of proven technology in grid-tied markets in cooperation with large utilities. In absolute terms, DOE support would still be substantial (as it was in the TVP), but would be relatively lower as a percentage of total project cost.

The benefits derived from this type of program would be substantial.

- Experience in distributed markets builds public acceptance for utility-scale adoption of marine energy technologies in a way that research and development cannot.
- Demonstrations of a broader set of technologies can identify and address problematic "soft costs" prior to technology convergence, when "soft costs" may be locked for a particular technology.
- Demonstrations in distributed markets allow practical resource estimates to be credibly refined in utility-scale markets.
- Commercial projects in distributed markets will need to demonstrate multi-year longevity – this is difficult to do at test facilities with a limited number of berths.
- Demonstration in new environments invariably identifies new technology and operational challenges to be overcome.

Overall, commercial demonstrations of transformative technology in distributed markets can significantly advance Technology Readiness Levels and Technology Performance Levels.

5. *What is your projection of what will be the highest need research areas in future years?*

At a macro level, the maturation of high TPL technologies from TRL 4-5 to TRL 6+ and cost reduction for high TPL technologies as they move along the development path are the two most important research areas in future years.

The development of sub-sea connectors, low cost installation methodologies and highly efficient power electronics (to convert low frequency AC power into transmission quality power with high efficiency and reliability) are expected to be additional high need research areas in future years.

Thank you for the opportunity to provide comments on the Department of Energy's Request for Information on Laboratory-Scale and Open Water Testing of Marine and Hydrokinetic Systems. We welcome any questions or feedback.

Sincerely,

Linda Church Ciocci

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