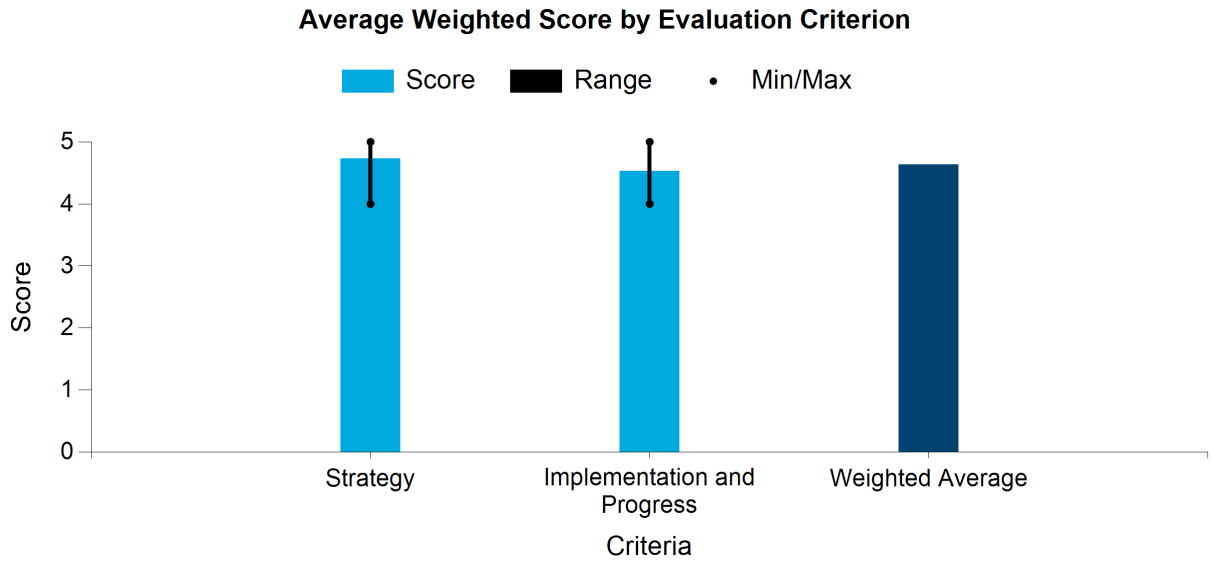
Marine Energy Program Evaluation

WPTO

WBS:	2
Presenter(s):	Tim Ramsey



Aggregated Reviewer Comments

- Regarding the strategy, the program has a defined strategy that reflects both the needs of the industry and the stakeholders and challenges faced. The key results from each of the four activities—especially around testing of devices both in the lab and on site and improving regulatory efficiencies—are key to move the industry forward. Focusing on the Data Access, Analytics, and Workforce Development projects, while all the projects are very impressive with useful outputs being produced, at the moment there is not enough evidence that these projects have resulted in improved regulatory efficiencies or reduced uncertainty around environmental impacts. However, this might be due to the early stages of the projects given that all the tools have a huge potential to streamline permitting and licensing if widely used by developers and regulators. Specific on the Workforce Development projects, it is unclear if the program will attract people who do not have a previous interest in the area or knowledge of the field. It would be useful to clarify with whom the resources are being shared. Overall, the program priorities, investments, and outcomes were clearly communicated. The technologies, tools, and studies funded do achieve the stated outcomes from the MYPP; however, the reviewer found it hard to judge if these are the most relevant projects or if they will have the greatest impact, especially on the long term.
- The MYPP is an excellent and well-written document that clearly sets out the strategy of the WPTO with a rational plan to deliver its goals in the short and longer term. The wider requirements of successful technology development are considered (such as the requirement for suitable testing facilities) and objectives set out to deliver on these requirements as well. The strategy is clearly being delivered by a passionate and capable team that appears adaptable and reasonable when dealing with project teams to ensure the optimal outputs for the industry. The reviewer also emphasized funding of at-sea demonstration of technologies will be vitally important moving forward and takes significant funding. The only way to deliver this will be through significant

funding opportunities. If WPTO funds are constrained, then there will need to be some selection of leading technologies for funding. It will be important to ensure sufficient funds are allocated if maximum benefit is to be realized. Significantly limiting funding has the potential to curtail deployments and, in the worst cases, lead to health, safety, and environment concerns during deployments as cheaper, more risky options are selected instead of the safest. When larger-scale at-sea deployments commence, there needs to be visibility of expected onward opportunities and financial support (if needed) through the so-called valley of death—if this is not in place there is a very real danger that good technologies fall away and the potential benefits of previous funding are lowered. Where projects are in the program for a long time, this could be symptomatic of the fact that funding for growth toward larger-scale testing is not currently available, and projects are therefore crafted that fit funding availability until such time as other funds become available. It may be important to engage with these companies to understand their "money no object" plans, and then see how that would fit with the wider program aims and if assistance is possible. Short-term, staged funding can be problematic for companies as it is a never-ending cycle of project application and raising. More longer-term funding will enable companies to have a less meandering route through technology development and will enable them to concentrate on the technology development itself. It would be great to see longer-term funding pathways being developed (with funding gates, if necessary, to ensure projects are delivering according to plan). This would give confidence to the developers and potential investors that continued funding assistance would be available through the technology development stage. Collaborations are key—at the moment there are predominantly full wave, tidal, and current energy converter (CEC) systems being developed and funded rather than smaller, focused projects that could focus on enabling technologies that will also be an integral part of the onwards success of the industry. There are many potential opportunities for collaborations in this space that could deliver real benefits to the industry. It may also be a great way to get technology transfer into the industry (industry doing funded projects on a specific component or system that is of need to a developer). Although valuable projects, the reviewer felt that some projects within the technology-specific workstream would sit better within the foundational R&D stream. If only limited funds are available for each stream, then this may be more important than it otherwise may seem. A number of projects could potentially benefit from linking in with previous international developers or expertise that relates to similar concepts. Leveraging this expertise could provide some projects with an initial boost and overall deliver better value and more developed technology quicker.

- The strategy is in line with the MYPP. There are probably some ways to improve funding mechanisms. On the implementation side, it seems that sometimes the selection for funding some technologies is not very clear. Where technologies have been tested or tried before, the rationale on the reason to return to the technology should be carefully considered. The reviewer also notes some focus on common technologies could favor a wider set of technologies.
- The WPTO is doing a superb job of identifying and funding a suite of initiatives from technology development and device testing to workforce development, data sharing, and public engagement that are collectively advancing the implementation of marine renewable energy in the United States. Moreover, the innovations supported through the WPTO have implications on a global scale, and advances facilitated through this program have worldwide applications for the sustainable transition to renewable sources of marine energy. As this program moves forward, it would be wise for the program to promote opportunities for funded projects to engage with end-users and regulators, and where possible, to advocate for the publication of research findings in peer-reviewed journals. This will add credibility to funded projects and provide regulators the protection they need from public scrutiny for permitted projects (i.e., risk reduction for regulators due to the scientific peer-review process).
- The Marine Energy Program is clearly structured and has a strong MYPP, which addresses many of the key issues affecting the development of wave and hydrokinetic energy conversion systems. The Foundational program provides a good opportunity for blue skies thinking and the investigation of oddball ideas that may have a significant impact (or may not). This is a critical part of any research, development, and demonstration

program, and the WPTO should continue to fund such activities. The focus on co-design for energy converters and the development of underpinning software tools is excellent and is world leading. In particular, the development of open-source software tools and models is to be commended and must be continued. Of particular concern was the limited number of stakeholders engaged with the program. Only three wave energy companies and one MHK company are involved in foundational R&D, and these companies are often the only stakeholder representatives in a project. Wider stakeholder engagement is critical so lessons learned are shared widely, enabling the overall development of the sector. Another concern is that there are clear linkages and synergies between projects with the risk that work is duplicated or opportunities missed as each team is working in a silo. The reviewer strongly recommends that DOE organizes intra-project events to share progress and discuss common issues. This was achieved in the UK through the Supergen program, where the funders made it a condition of funding that university research teams worked closely with each other. Similar things have been done with companies receiving funding from Wave Energy Scotland. Everyone benefits from this approach, which also ensures better value for money for the taxpayer. Furthermore, project teams must be encouraged to engage with the international community, leveraging learning and accelerating development by considering a broader range of options/decision needs. The reviewer also expressed concern that foundational technology and component development projects are not considering the impact of the real ocean environment (multidirectional waves, wind driven, ocean and tidal currents, turbulence, etc.) as part of a co-design approach, and this leads to weaknesses in designing and expensive lessons being learned at sea. Testing must be performed on the bench or at scale in hydrodynamic laboratories before putting steel in the ocean. An excellent maxim is that you should not go to sea until you believe you have nothing to learn by doing so! (You will still learn a lot.) Tests need to simulate the real environmental conditions with multidirectional, multispectral waves, sheared and turbulent ocean and tidal currents, etc. Back-to-back power take-off (PTO) test rigs need to be driven by realistic "software-in-the-loop" models, while hydrodynamic tests need to be performed in facilities able to create "realistic" conditions. At the FloWave facility in Edinburgh, a lot of work was done to synthesize a library of sea conditions representative of both survival and production seas at the European Marine Energy Centre (EMEC) wave site. These are now part of the standard testing required by Wave Energy Scotland/Europe Wave. They include mixed seas with ocean swell mixed with local, wind-driven storm seas. If additional facilities need to be added to the TEAMER program network to achieve this, it should be done. It may be much better value to fund access to international facilities such as FloWave rather than to build your own $15 million facility. At-sea testing at specific test sites should only be mandated when the test site is ready and fully able to accept devices for test. DOE should work with test sites and their local port and harbor facilities to ensure that there are adequate berth and laying down areas available to accommodate devices during test programs. This will encourage the development of local supply chains to support developers coming to test.

- This is a wide ranging and connected program of research and innovation, which connects foundational research through to demonstration and standards development, as well as curriculum, skills, and workforce development. Both utility-scale and niche applications for marine energy research are explored. Public engagement and dissemination are considered highly important throughout the program, and there is an impressive level of ambition. It would be useful to consider how to engage a more cross-disciplinary approach to the R&D as the challenges of marine energy development will require marine science as well as engineering in order to develop technology solutions in harmony with nature. Furthermore, some of the biggest challenges in the energy transition are bringing people along with the next technologies and behaviors, and so social scientists have a valuable role in helping design projects that can achieve public acceptance and adoption.
- The WPTO Marine Energy Program overall is doing a very good job in planning and implementing marine energy within the United States. The planning and design for implementation of marine energy is well thought out and appears to be working in a positive direction. The reviewer was extremely impressed with the organization, efficiency, and smooth running of the peer review process. All staff were well versed in the topic areas and kept the presentations and review process running on time and effective for all involved.

- A well-balanced program with good breadth and depth in all areas. Excellent management of the overall program by committed WPTO staff and leadership. Consideration should be given if the program can sustain its current breadth as its technologies initiatives require more funding and WPTO staff management time as they mature in scale and TRL.
- The presenter gave a very useful, high-level overview of the program, its vision, and mission. The program is very broad in scope, nurturing a number of interlinked technologies. It seemed during later review events that they were not as clearly connected to the broader scope, or they did not realize/display that connection. This may have led to some projects viewing their efforts overly narrowly. (The reviewer specifically referenced the cables project, which has equal applications for offshore wind as for offshore waves and could seek broader stakeholders/inputs. The reviewer cited additional examples, such as some of the smaller kW units that could more broadly assist offshore needs or pumps designed for a particular need, but noted there could be many others.) The reviewer noted a graphic showing reviewers what they were about to see mapped out on a strategic continuum would be helpful, and it might also be helpful to the PIs in how they view their efforts. PIs could benefit from better seeing the interlinkages between their projects.
- The Marine Energy Program is a comprehensive and impressive approach to addressing the needs and the challenges of fostering development of the marine energy sector for the United States. Given the urgency for development of decarbonized sources of energy, distributed energy production, and the nascent state of the marine energy sector, the Marine Energy Program is profoundly important. This reviewer has been very impressed with all aspects of the Marine Energy Program, and well-crafted documents articulated the need and justification for the program and the vision, contributions, and accomplishments of the funded projects. The quality of the execution of the projects is encouraging. The reviewer strongly recommends the development of a series of workshops to help bring the results of the breadth and depth of this work to researchers, developers, and regulators who are not actively a part of the network formed by those within projects funded by WPTO. The advantages of such a series of workshops include the potential to accelerate uptake and commercial viability, reduce time to permitting, and build a wider understanding of the transferability of the technologies and methodologies tested and developed. The work of the program is vitally important.
- The vision outlined in the presentation is clear and provides a forward-thinking methodology. The commitment to DEI is impactful, and the team should be commended for their dedication. TEAMER is great! It is a way to utilize and smartly use multiple resources from numerical modeling to experimental testing. The goal of disseminating results and reducing "time to water" is a challenging but much needed step to advance the marine energy sector. With the rapid growth of the blue economy, the reviewer suggests more engagement with industry and K-16 to train the workforce needed to meet future demand. Many K-16 students are unaware of marine-based renewable energy; most are only aware of solar and wind.
- The Marine Energy Program is well run and successfully addressing the objectives of the MYPP. The overview presented by the program manager demonstrated an understanding of these objectives and the needs of the industry and stakeholders, and clearly communicated the rationale and strategy for the program. This rationale and strategy were subsequently demonstrated in the variety of projects presented in the course of the peer review. The program is appropriately funding the many different areas of technology that require development for marine energy to be successful. For example, the program funds sensor development for measuring the environmental effects of marine energy devices as well as the development of the marine energy devices themselves. The former will assist regulators in judging permit applications for the latter. Individual projects are monitored by WPTO staff to ensure that taxpayer funds are properly spent and schedules and milestones are followed as closely as practical. Inevitable delays, principally due to field tests facilities, are handled in an open and professional manner. As stated above, the program is funding technologies that address the many steps needed—such as planning, designing, and manufacturing (including material selection)—in the development of a marine energy device, control hardware to work with PTO mechanisms, and assistance in the testing of prototypes in laboratory and field test sites. This testing assistance is accomplished through several

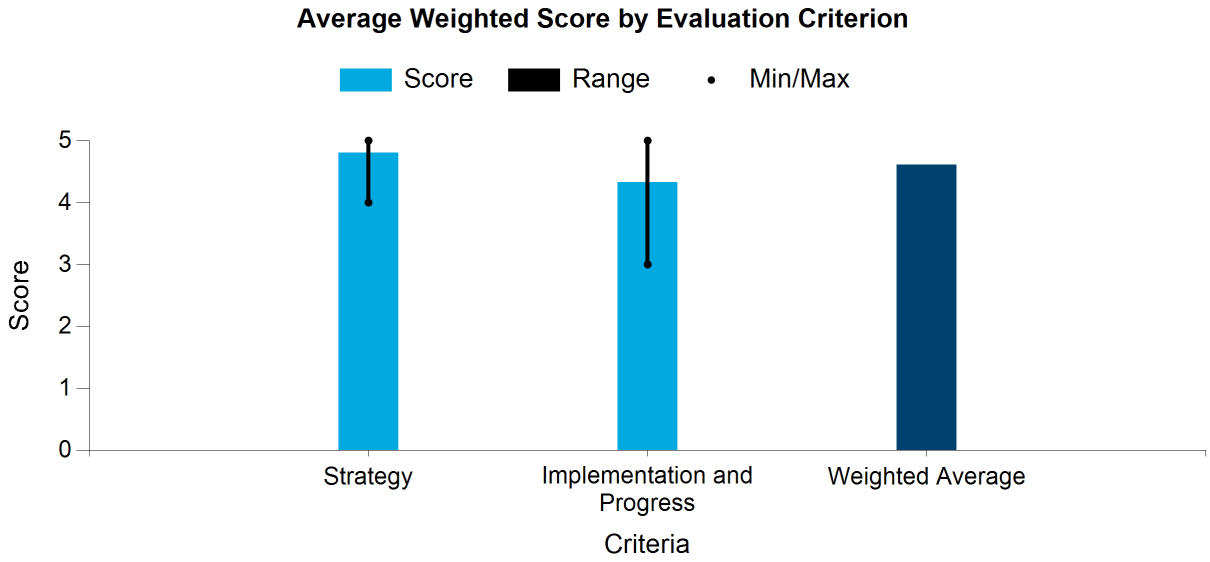
projects, specifically Triton, TEAMER, National Lab and University Collaboration for MHK Instrumentation and Data Processing Tools, NMREC Infrastructure Upgrades, and PacWave. These efforts, many of which make very effective use of leveraged funds from other sources, provide significant aid to marine energy device developers by supplementing their in-house expertise and making test facilities available, thereby accelerating the development and eventual deployment of renewable marine energy.

- The Marine Energy Program being delivered by the WPTO is a diverse range of projects, each of which will enable and accelerate the development of marine energy. The Reducing Barriers to Testing Activity Area panel looked closely at the projects to ascertain if they would enable access to open-water, grid-connected testing facilities, support environmental monitoring, and provide technologies, tools, and data collection to understand potential environmental risks. The projects were largely of a very high caliber with good range of scope in all areas, and there appeared to be a good degree of collaboration and consideration of the projects as part of a program. The work was very focused on wave energy and impact assessment. This is reflective of the prominent industry in the United States and the available test facilities already in place. It is apparent, however, that there should be a review of the investments to ensure all blue economic potential end users have the ability to benefit, where practicable. There may be multiple end users, not simply marine energy, that could benefit from the innovation and research, as well as the infrastructure investment taking place. The program, if fully successful, could yield extensive facilities and information of use to the sector, and this should be as broadly disseminated as possible within the domestic research, industry, and end-user communities but also internationally.
- The work done to date has been excellent. There is a great focus on and understanding of the industry. The reviewer was impressed with how the team helps companies focus their energy and planning and, at the same time, pushes them along the development pathway. The willingness to explore the different tech has been admirable; it is important to allow blue-sky and creative solutions be investigated. The planning is well structured, and the growth in scale in the programs is very clear and helps to converge the industry toward some defined standard ranges and sizes, if not yet to designs. The access to these programs and the kinds of proposals that are considered shows that there is a fair process that opens up this kind of funding to a wide audience and gives small developers a chance to build their designs. The funding that can be accessed by companies that have been previously supported is critical for companies to get to the TRL that will allow them to attract investment. In the private sector, investment in emerging tech is almost nonexistent, and the ability to apply for public funds ensures creative, innovative technology development is ongoing during leaner times.
- This was a great presentation. Year-long field tests through a year's worth of wave conditions is an excellent idea. The reviewer recommends considering more direct engagement with coastal communities (perhaps by establishing little offices), city-run incubator programs, university tech development offices, etc., who often try to shop creative ideas to the wrong groups of people. The reviewer thought that perhaps some of the ideas that come out of such interactions could bear more fruit than keeping the same old tried-and-tested designs funded through years until they report measurable success. The reviewer noted there is value in such success, too. However, the reviewer suspected ideas that originate on the ground could more easily attract private investors and make quicker progress through technological and logistical hurdles. The reviewer also requested the consideration of their comments on the resource characterization project presented by Levi Kilcher on behalf of NREL, PNNL, and Sandia.

Powering the Blue Economy Evaluation

WPTO

WBS:	2.2.5
Presenter(s):	Tessa Greco



Aggregated Reviewer Comments

- The PBE program has a clear, long-term strategy, strategic approaches, and future direction that reflect an understanding of the industry needs. The near-term demonstration opportunities presented are brilliant and closely tied to the program's strategic direction. The reviewer was impressed with the usage of wave power for desalinization and was not aware of the project before. Understanding the effect of marine renewables on coastal communities is key to avoid any potential conflicts between sea-users, thus seeing programs such as the National Sea Grant Office collaboration being created is fantastic. Similar, using the renewable energy for aquaculture and powering ocean research will open new market opportunities. Overall, the funding opportunities align with near-term PBE opportunities.
- The PBE Initiative is an excellent way to develop water power technologies in markets where the cost is not a great barrier. Lessons learned here in smaller-scale deployments will no doubt have applicability to larger wave energy technology developments. Focus on this initiative shows an understanding of how technology development at a smaller scale (or with fewer constraints on cost) can occur and feed into wider goals. The rationale for the PBE Initiative is well set out and being delivered by a very capable team. Some of the projects focusing on the PBE Initiative would benefit from additional support with end-user engagement to quantify the problem and requirements.
- The strategy seems to target the best entry points (local communities without access to the electricity grid and aquaculture), but it would be interesting to quantify the impact and the time to impact in the blue economy on a large scale. Also, the successful implementation of marine energy in these areas will be dependent on the reliability of the systems (or strategy to keep the marine energy supply reliable). The implementation has been successful in mobilizing parts of society to marine energy. The use of prizes and competitions were useful, but the reviewer expressed concern with the support for cooperation with technology developers and the impression that the problems highlighted in the prize contest are the only aspects to overcome.

- The PBE Initiative is a well-conceived and strategic approach for integrating with and meeting industrial partners' and end users' needs in the marine energy sector. This initiative supports the WPTO strategy and mission and works with partners to develop solutions to address energy challenges facing partners in the private and public sectors. The establishment of prizes and financial support for entrepreneurs pursuing novel innovations at small businesses is key for developing new technologies that can ensure a sustainable transition to renewable sources of energy from the marine environment. The R&D being facilitated through this program are cutting edge and require ongoing support. The program is also making great strides toward reducing barriers to device testing in situ. A future focus on access to data, workforce development, and innovative analytic approaches is forward thinking and will help ensure the success of marine renewable energy technologies in the future.
- PBE is encouraging an appropriate route to market for developers with devices being designed and tested at small scale for niche applications (desalination, ocean observation, aquaculture, off-grid communities, etc.) where energy commands a much higher price than grid power or where existing small-scale diesel generation can be displaced. This is a very important route and enables developers to learn by doing much more cost effectively than can be done at grid scale. As with the broader MHK program, stakeholder engagement is poor and needs to be much wider. There are strong opportunities in this area for collaborating with other DOE and NOAA programs (including hydrogen), and these should be explored. EMEC has shown that combining tidal energy with onshore wind allows curtailed electricity (the local grid is very weak) to be used to manufacture hydrogen cost effectively, and this could be used for a number of applications (including ferries, road transport, aviation and renewable heat). The Waves to Water program is an excellent example of what can be achieved, though it should be remembered that traditional desalination, potable water treatment, and wastewater treatment are very energy intensive processes that, like hydrogen production, can be used to shift electricity demand patterns. Local communities will be very interested in this work and should participate as stakeholders. It is important that the wider supply chain is engaged with. The reviewer expressed concern that in the dynamic export cable project the research team was working with a wave energy developer and not with a cable manufacturer. This led to real problems with the supply of cable and the loss of some critical parts of the project's work program. Had they been working with a cable manufacturer with a large potential market (wave, floating wind, autonomous vehicle charging platforms, etc.), much more could have been achieved. Finally, at-sea testing should only be undertaken when developers believe they have nothing to learn by doing the sea trial. Devices must be tested in the lab (using hydrodynamic labs and back-to-back PTO test systems) under realistic conditions before going to sea. This will be much more cost effective for the program and will lead to much less disappointment.
- PBE is an important strand of the WPTO program. It will assist with the development of marine energy through targeting high-value markets that will benefit from marine energy in order for them to be decarbonized. It is also an important route for marine energy technology to be tried and tested at smaller scale before being developed further and demonstrated at grid scale. Thus, the applications being investigated through the PBE program are valuable in their own right and also as part of the pathway to cost reduction for utility-scale marine energy development. The combination of foundational research, industry partnership innovation funding, and prizes is a good mix and provides opportunity and involvement of different stakeholder groups within the landscape. The dissemination and public engagement should continue to be a strong part of this.
- The PBE program is well thought out, and I particularly like the kilowatts to gigawatts thinking. PBE does an excellent job looking at each step in the needs and process for marine energy from small-scale and local community needs and concerns/impacts to R&D with developers and research institutions. With the growing of marine energy and the blue economy, the addition to the PBE organizational structure of a PBE ambassador and PBE administration and coordination offices should provide good support and control for the growth of PBE in the future. The collaboration with other federal agencies, industry, national labs, and involved communities is a key part for success of PBE.

- A well-balanced program with good breadth and depth in all PBE areas. Excellent management of the overall program by committed WPTO staff and leadership. Consideration should be given if the PBE Initiative can also be funded from other sources (i.e., end users from the oil and gas, defense, autonomous underwater vehicle sectors). Consideration should also be given to ensure there are synergies between PBE and utility scales of devices.
- The presenter gave a very useful, high-level overview of the program, its vision, and mission. The program is very broad in scope, nurturing a number of interlinked technologies. It seemed during later review events that they were not as clearly connected to the broader scope, or they did not realize/display that connection. This may have led to some projects viewing their efforts overly narrowly (The reviewer specifically referenced the cables project, which has equal applications for offshore wind as for offshore waves and could seek broader stakeholders/inputs. The reviewer cited additional examples, such as some of the smaller kW units that could more broadly assist offshore needs or pumps designed for a particular need, but noted there could be many others.) The reviewer noted a graphic showing reviewers what they were about to see mapped out on a strategic continuum would be helpful, and it might also be helpful to the PIs in how they view their efforts. PIs could benefit from better seeing the interlinkages between their projects.
- PBE has articulated a well-defined strategy to meet the needs—both broad (e.g., grid-scale) and specific (e.g., targeted needs of aquaculture or desalination)—within the PBE concept. Informing the PBE strategy is an understanding as demonstrated by the synthesis provided in the 2019 report and the collaborations across DOE offices and other federal agencies. The challenges are an innovative approach to identifying the projects deserved of funding.
- The attempt to engage small businesses though SBIR awards, competitions, and monetary prizes is a great idea. There is a broad range of applications listed for the blue economy, and this should really broaden and expand the much needed future workforce. It would be great for the team to identify the need to engage industry as next steps. The reviewer also recommended engagement with K-16, even if just for awareness.
- The PBE activity area is well run and successfully addressing the objectives of the MYPP. The diversity of the projects that it has chosen to fund demonstrates that the WPTO staff in charge of the activity understands the challenges of the industry and stakeholders. It is likely to achieve its goals and objectives based on the success of its current projects and the plans for future projects.
- Marine energy has a key role to play in developing the blue economy. While the eight areas for potential marine energy application (ocean observation, underwater vehicle charging, aquaculture, algae farming, underwater mining, desalination, and powering isolated communities) will certainly be part of the economic development of marine energy, the sector is still at an early technical stage of development and, therefore, it may not be commercial to apply marine technology to these areas yet. Focus should be, at this stage, on a program that accelerates and de-risks scaling and innovation in marine energy to reduce costs. At-scale deployments, including of larger devices and arrays, will be critical to ensuring the technology becomes economic and can fully support these novel applications. The marine energy industry can see a unique and diverse application of kinetic energy devices in a broad range of environments, and this reflects the diversity in the technology types. Large-scale convergence of technology solutions, as has been done in wind energy, is unlikely due to the nature of the resource form which kinetic energy is extracted. The program aims, at this stage, are aligned within the sector, but there should be continuous review and engagement with technologies and potential end users or applications to ensure funding is focused on the correct stage and application of the marine technologies it is supporting.
- The goals of the program are clear, and the kinds of work done are meeting those goals. This is a wonderful program. The early stage and, in particular, the prizes encourage development and participation in the ocean energy space. The opportunity for outreach is high with this program. The marine market focus is a good use of funds at this scale. Desalination and island grids are applications that benefit greatly from this kind of funding

and are often places for the training of highly qualified persons. This kind of funding will attract researchers with new and innovative ideas. While the reviewer believes that a large-scale commercial project is necessary for the industry at this point in marine energy development, they also fully support these types of programs and are excited about the wide impact they can have. This one is particularly well designed and the clarity is exceptional.

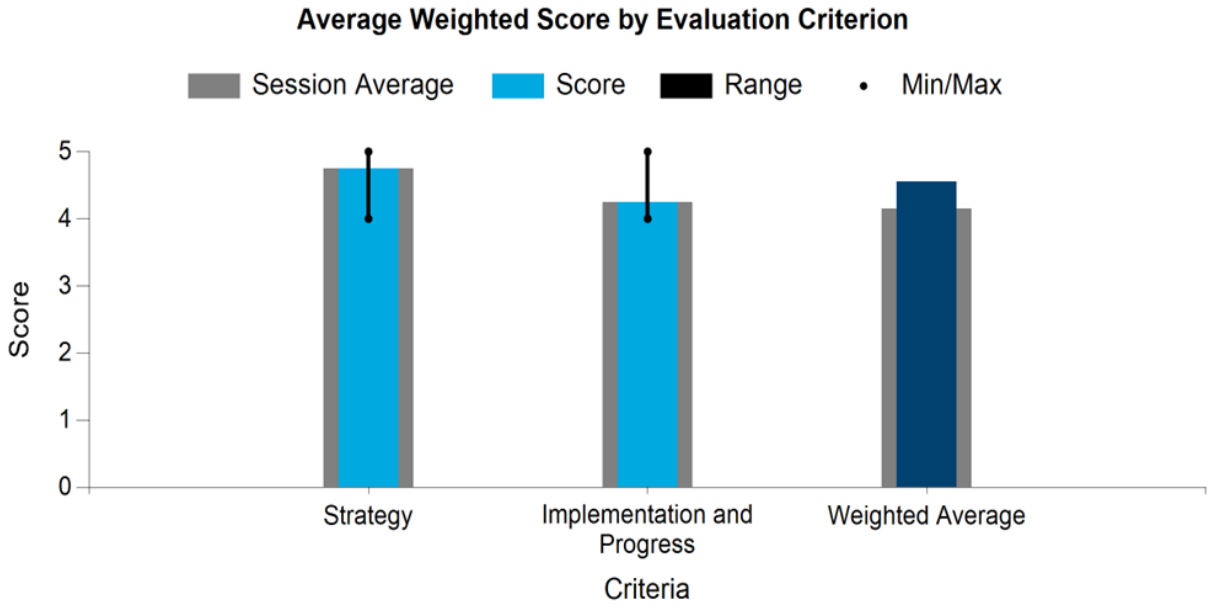
- Excellent work and excellent presentation. The reviewer believes the PBE program is one of the great major developments to emerge from DOE's engagement in water power. This is one area where the reviewer sees a merger of interests between what people on the ground need and DOE's priorities. The reviewer encourages continuing this program regardless of whether or not it turns out to make it easier to transition the conversion technologies to utility-scale operation.

Foundational R&D

Activity Area Evaluation

WPTO

WBS:	2.1
Presenter(s):	William McShane



Aggregated Reviewer Comments

- The Foundational R&D program is well thought out and has been carefully constructed against the needs of the sector. The reviewer welcomed the strong focus on co-design methodologies, which are very important for devices (particularly wave and MHK) that are subjected to a complex environment with forces created by wave action, tidal and ocean currents, shear profiles, wind-driven currents, and large-scale turbulent structures. If these water power technologies are to succeed in power generation or in other applications such as desalination, they must be both reliable and cost effective. Increasing reliability and availability drives down costs, reducing LCOE. Evidence from the fixed offshore wind industry in the UK and Europe has shown that a strong focus on driving down O&M costs is also needed. Co-design should make this possible, but perhaps WPTO needs to be firmer on this requirement with project proposers. The projects developing WEC optimization and modeling tools (particularly WEC-Sim) are delivering world-leading tools and are an area of which WPTO should be extremely proud. They are a major and important output of the foundational R&D work and should be continued. While ongoing development of WEC-Sim may not need the same level of resource, it is critical that the software is supported and maintained in the long term and that training and promotion of the tool set continues. The reviewer expressed no doubt that the national labs are capable of doing this—noting that they have with other software tools for flow visualization (Sandia) and wind energy (NREL)—but is unsure of the funding mechanisms. The seedling and sapling program is a strength, and it should be the roll of a foundational R&D program to look at wacky ideas and encourage blue sky thinking. One key area of concern is that much of the work in the water power program is focusing on what is an international grand challenge. There is a risk that funded work is duplicating (or worse, ignoring) work done elsewhere and, thus, WPTO is not ensuring best value for the taxpayer. Stronger international articulation would be beneficial across the whole water power program with projects able to draw on experts and technology developers in other countries (to

share learning and help to develop a domestic market) or to allow access to world-leading and unique test facilities and to gain experience from working with long-established test sites. One project specific point that needs careful consideration is that testing of a device had been held up by delays at the Hawaii wave test site while the infrastructure at the site was updated. It is less than ideal that risks owned by the test site should be passed onto a developer or a demonstration project, especially when this causes significant problems at the local port. WPTO should be wary of mandating testing at a particular location as a condition of funding if the test site is not ready to accept the device. It is also important that the test site works closely with the local community to build relationships and that they strive to have laying down areas and berths where developers can store equipment while it is either waiting to be deployed or waiting for repair prior to redeployment. As EMEC says, the point of field testing is not to succeed but to fail. If we do not fail (sometimes), we do not learn. Finally, it is clear that WPTO has been working closely with project teams to help them deal with COVID-related delays and other problems. One presenter told reviewers WPTO has been extremely helpful in supporting their project so far, indicating WPTO has been positive and responsive to requests and has been a pleasure to work with. WPTO should be very proud of this positive feedback; many funding agencies around the world would not get such praise.

- This is an impressive program for supporting research in marine renewable energy, and there are good examples of impact over a sustained period and very broad range (e.g., the software development and support WEC-Sim, which has a very wide user base internationally). The focus of the research program is well aligned with the needs of the sector, and it is clear there is strong consultation in developing the research themes to be addressed. It would be good to see more of the industry, both device developers and supply chain, involved in the foundational research projects. There appear to be a few, and they are often involved in more than one project. There is quite some variation in the level of dissemination and public engagement embarked on by the different projects within this grouping. Some have excellent engagement and dissemination outputs openly available, whereas others appear not to have engaged outside of the project team or published their findings. Many of the projects have clear linkages and would benefit from collaboration or sharing of findings during the projects; this could be facilitated through workshops where all projects present to one another under nondisclosure agreements, if necessary, so they can find identify areas of complementary work or where it makes sense to share effort in order to achieve more. There is also a linkage with other areas of net-zero-related research, such as energy integration, hydrogen and other storage, and offshore wind; opportunities for joint funding of projects with other offices could be explored. In addition, further efforts to connect with and jointly fund research programs internationally would be recommended.
- The reviewer asked if there is a clear plan/trajectory for probable destinations of projects with various energy ratings and noted this could help broaden the field of stakeholders. The reviewer asked if there has been any thought to co-locating offshore wind fields with marine energy sites, noting this might also be a resource mapping issue, if they are not good for both. The reviewer noted this might help with some of the permitting issues of which the reviewer is aware.
- This component of the program is being managed in a thoughtful, methodical way and appears to be consistent with the MYPP. The seedling/sapling program is particularly praiseworthy and could ideally build a vibrant community of researchers within the national labs who can collaborate freely. The reviewer recommends the team perhaps also consider opening up the seedling programs to university-led collaborations with national labs.

Project Evaluations

Fatigue and Structural Load Analysis and Control for Variable Geometry Wave Energy Converters

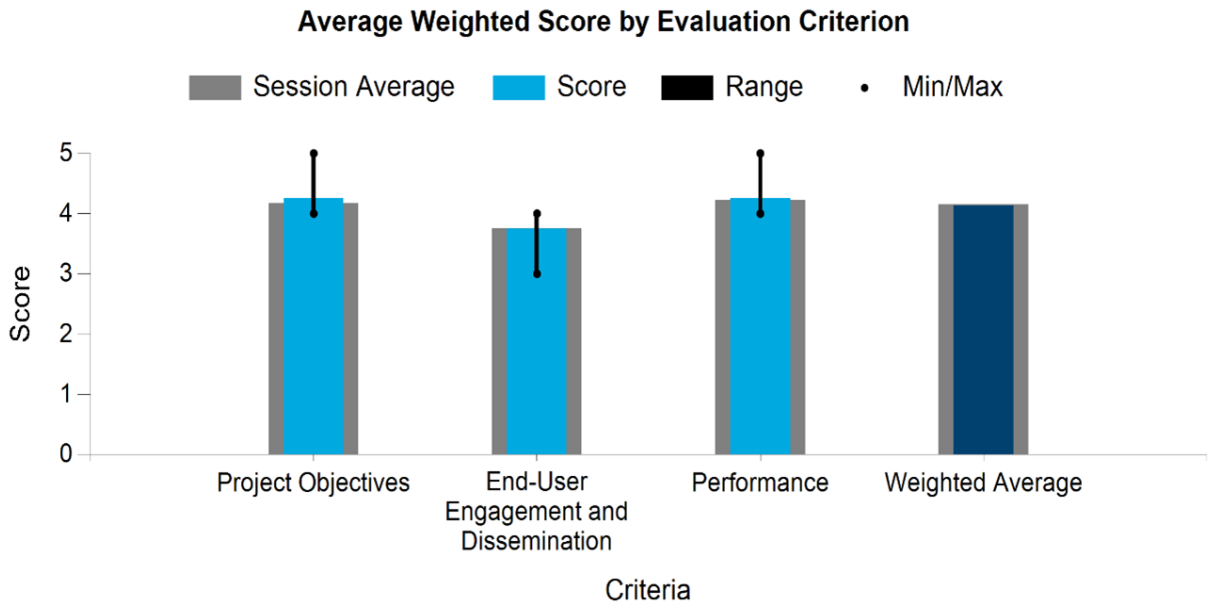
NREL

WBS:	2.1.2.403
Presenter(s):	Nathan Tom
Project Start Date:	08/01/2018
Planned Project End Date:	07/31/2022

Project Description

This research effort is a four-year, two-phase project designed to develop the next-generation control strategies for variable-geometry wave energy converters (VGWECs). VGWECs are designed such that their shape can be adjusted to reduce the forces the waves place on the WEC structure. For example, VGWECs create windows for waves to pass through so wave energy devices do not bear the full force of the ocean's power. This project aims to create a paradigm shift in WEC design by providing the option to control both wave hydrodynamics (to reduce wave pressure through shape change) and the PTO. The VGWEC control strategies expected to result from this project will maximize power, offer additional load-shedding capabilities (and thus help to reduce costs), and lower peak-to-average power ratios. The additional load shedding capability provided by shape-changing variable-geometry is expected to reduce the device structural mass and extend the sea states in which the device can operate. This is accomplished by limiting peak loading, which can help reduce LCOE.

This project aims to reduce the LCOE through a structural optimization to reduce the required WEC steel thickness, which is directly coupled to capital costs. This optimization is only possible if greater control over peak loads is enabled by the hydrodynamic load control provided by the variable-geometry concept. In this project, there will be an attempt to incorporate the structural flexibility in the hydrodynamic models so that the structural stress can be analyzed to determine the location and magnitude of peak stress concentrations.



Aggregated Reviewer Comments

- This is an interesting piece of work that is considering varying the geometry of a WEC as part of the control strategy. While a lot of work had been done with good quality modeling of the different geometries, it was difficult to see how this work addressed the fatigue and structural load analysis part of the project as there was more concentration on the control aspects. That said, the work is excellent and shows promises in the ability to use geometric control. Maguire and Ingram ("On Geometric Design Considerations and Control Methodologies for Absorbing Wavemakers," Coastal Engineering, Vol. 58, no. 2, 135-142, 2011. DOI: 10.1016/j.coastaleng.2010.09.002.) showed that this could give a broad range of absorption characteristics for wave makers by using geometric design for one frequency and spring/damping control at a different one. To do this, geometry needs to build into the motion equations for the WEC and to look at changes in the spring, mass, and damping forces with changing geometry. The reviewer cannot see that the same extension of the resonant frequencies should not also be possible. Unfortunately, many of these effects are non-linear, and the weakness of the linear theory will need to be considered. The reviewer noted that the experimental program will use fixed but changeable WEC geometries (following the approach used by Quoceant in the Wave Energy Scotland Novel Wave Energy Convertor competition). While this works well, one needs a wave tank with excellent repeatability and must be aware that the response of the flexible structure to wave loading will not be modeled. To cope with flexibility, WEC-Sim may need to be modified. This is an excellent foundational R&D project and has good dissemination of results.
- This is a very interesting project that is well aligned with the objectives of the program and with potential for disruptive technology and step change in LCOE. A structured process is followed, and results are assessed at each stage: three types of VGWEC investigated and one down-selected for wave tank testing. There is some delay in the research program, but no cost extension required, and the second phase of the project to complete wave tank testing is now underway, as is the hardware in the loop testing. The results are disseminated through appropriate channels to academia and WEC developers, and a patent application underway. The investigators may be interested in studies carried out by Quoceant in a Pelamis-type study.
- The reviewer inquired how this approach handles a wide range of sea conditions and about the expected limits on the inflation mechanism. It would have been good to see more information on the design selection process, and how it changed the flow dynamics. Some hydrodynamical modeling would have been good to see. It would be useful to increase industry engagement; even though it is early there may be considerable interest in this design.
- Good work overall. Larger pictures and a clearer explanation of the three geometries would be helpful. It was not clear how work performed represents the title of the project. The reviewer inquired about the time constants for the shape change process in the chosen design and how much power would be needed to (reactive and resistive) bring about the shape changes.

Next Generation WEC PTO Co-Design

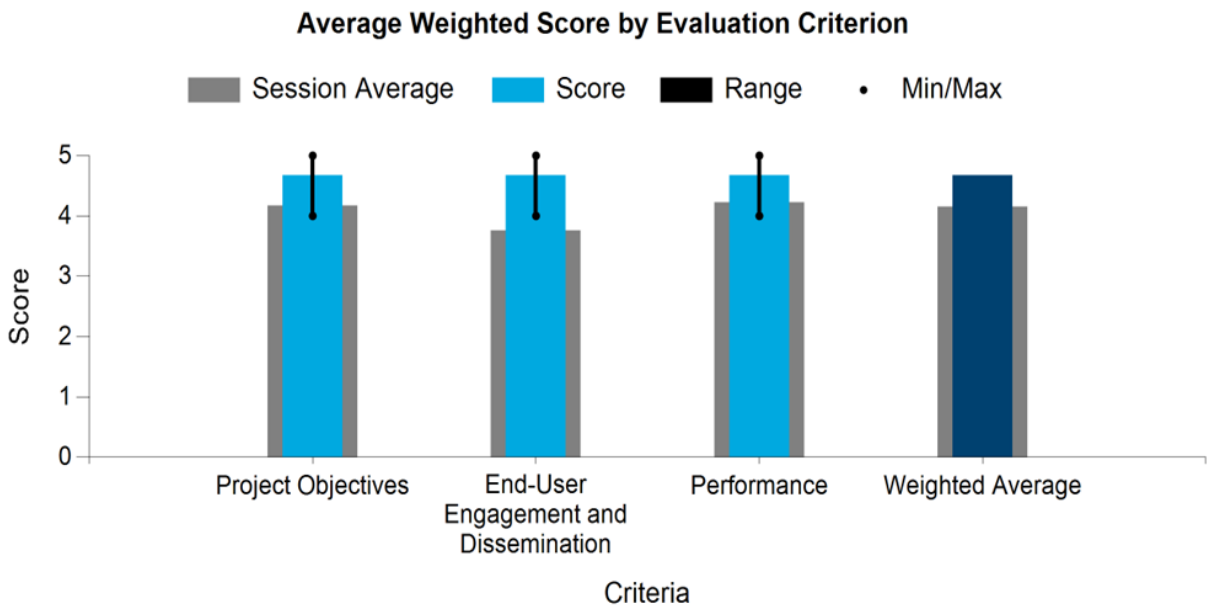
Sandia

WBS:	2.1.2.705
Presenter(s):	Ryan Coe
Project Start Date:	10/01/2019
Planned Project End Date:	09/30/2022

Project Description

WECs are unique from other existing energy generation technologies. Instead of converting relatively steady input mechanical energy that fluctuates about some mean (e.g., wind, nuclear, hydroelectric), WECs must absorb a purely oscillatory energy input. This unique quality necessitates the usage of advanced control to maximize energy generation and minimize LCOE. Control strategies can be used to shape the dynamic response of a WEC to achieve resonance and increase energy absorption by as much as 200%. However, WECs comprise complex hydrodynamic, mechanical, electrical, and sometimes hydraulic subsystems, all of which must be properly designed to be capable of efficiently implementing a control strategy in order to reap the benefits of advanced control.

This issue of designing the dynamic WEC system, of which the PTO and control systems are central components, to minimize LCOE is the central focus of this project. The project team applies impedance matching principles within a co-design framework to the holistic WEC system. This method of WEC PTO and control system design is being developed in a device-agnostic manner, enabling industry developers and researchers to apply the method to their own devices and produce dramatically better performing WECs.



Aggregated Reviewer Comments

- The importance of co-design for the development of WECs and other complex technologies is clear, and this project has been showcasing the approach and developing the tools required. It is a very impressive piece of work that is making excellent use of the open-source model to disseminate the software being developed. The use of control strategies that allow the full WEC PTO to be optimized and not just the hydrodynamic properties (as has been done in the past) are an important step forward. The industrial and academic outreach is strong with International Conference on Ocean, Offshore and Arctic Engineering workshops and a raft of papers

alongside the software repository. It was not clear from the presentation which devices it had been tested with, and this raises the question as to whether the stakeholder group is wide enough.

- This project focused on the development of a co-design wave to wire model and impedance matching framework for co-design, which could have significant impact on the WEC sector. A good number of co-design research papers have been published, and there is a strong level of public engagement and workshop activities. The open-source WEC-Sim and MATLAB code for co-design released through GitHub will be extremely valuable to the WEC community. The co-design methodology has been demonstrated for the Monterey Bay WEC project, and there is strong industry collaboration.
- The presenter provided excellent context, and the co-design idea seems to fit a deep need. Outreach so far is excellent, and it is good to see that the project has been demonstrated in more than just the Monterey Bay Aquarium Research Institute's WEC. The reviewer recommended further device/location testing to help expand utility.

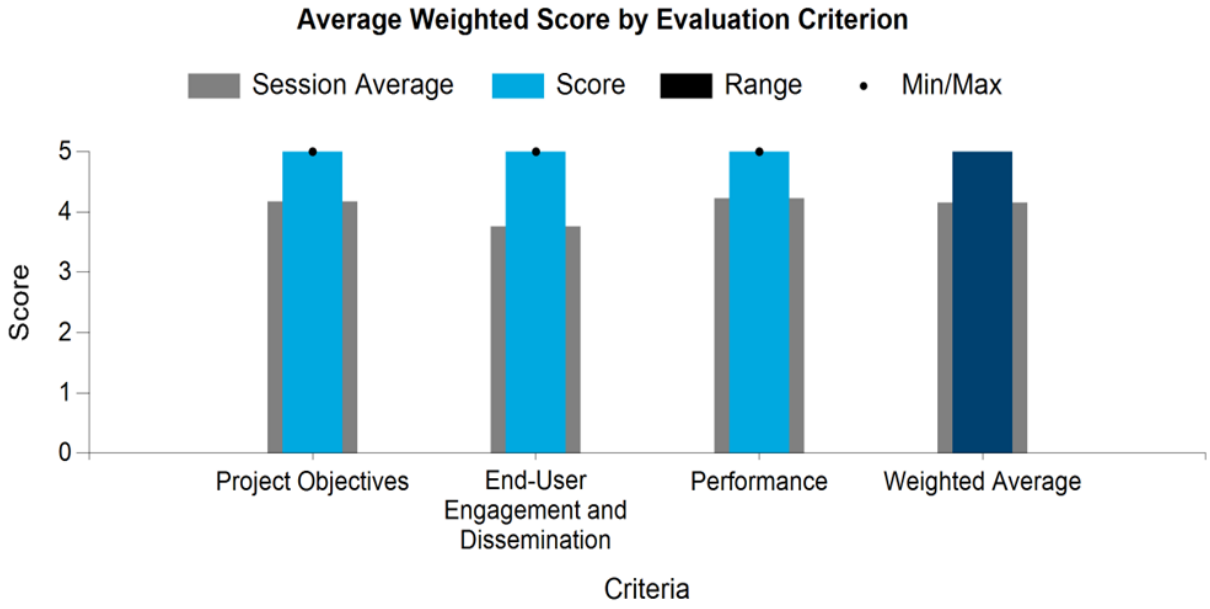
Wave Energy Converter Modeling

NREL, Sandia

WBS:	2.1.3.401
Presenter(s):	Dave Ogden; Kelley Ruehl
Project Start Date:	10/01/2014
Planned Project End Date:	09/30/2021

Project Description

WEC-Sim is an open-source software for simulating WECs. The software is developed in MATLAB/Simulink using the multibody dynamics solver Simscape Multibody. WEC-Sim has the ability to model devices comprised of bodies, joints, PTO systems, and mooring systems. WEC-Sim can model both rigid bodies and flexible bodies with generalized body modes. Simulations are performed in the time-domain by solving the governing WEC equations of motion in the six Cartesian degrees-of-freedom, plus any number of user-defined modes. The WEC-Sim Applications repository contains a wide variety of scenarios that WEC-Sim can be used to model, including desalination, mooring dynamics, nonlinear hydrodynamic bodies, passive yawing, batch simulations, and others. The software is flexible and can be adapted to many scenarios within the wave energy industry.



Aggregated Reviewer Comments

- The development pathway for the WEC-Sim tools continues to deliver outstanding progress and builds a strong user community. The team is making excellent use of the open-source software model and should be proud of their international recognition and software development prizes. Indeed, WPTO should also be celebrating this world-leading achievement. The use of a licensing model that allows WEC developers to hold private copies of the code with bespoke modules containing intellectual property-sensitive models is exactly what is needed by the sector. The reviewer hopes that the fact that WEC-Sim is being developed by national labs means that their project has longevity and that there will be continued support for the maintenance and support of the tool set once the development funding ceases.
- This is an excellent and impactful initiative; WEC-SIM software is widely used throughout the world and relied on for design of WECs and floating structures. The developments proposed for interoperability with the solvers is good. The reviewer also recommends pursuing international collaborations and interaction.

- The reviewer inquired about the plan for testing with other devices. The reviewer also encourages continuing to ensure this is compatible with other tools being developed, having found that a framework for tools and coupling their outputs is a key to long-lasting use.
- Excellent work. The reviewer inquired whether the project team is currently working with commercial 3D CAD/3D printing software makers. If not, that could be a path worth exploring.

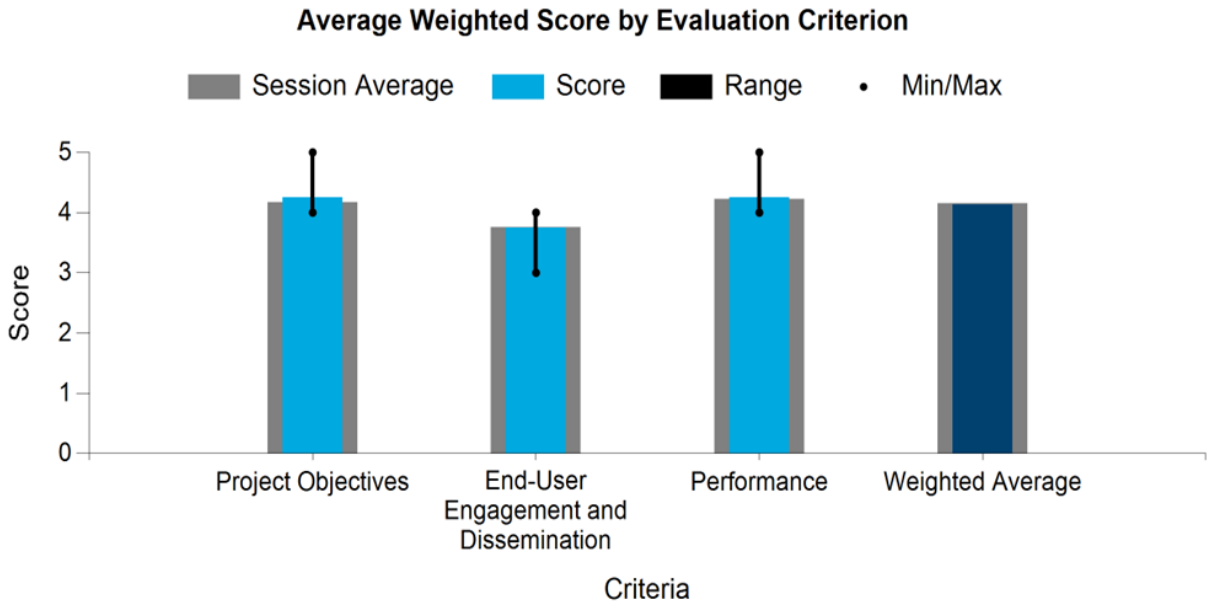
WEC Array Power Management and Output Simulation Tool

NREL

WBS:	2.1.3.404
Presenter(s):	Toan Tran
Project Start Date:	08/01/2018
Planned Project End Date:	09/30/2020

Project Description

An array of WEC devices have variations in power output due to the chaotic nature of waves. Eliminating or mitigating power fluctuations is important for reducing the integration impacts of WEC plants in both distribution and transmission grids and in standalone, isolated power systems. Reduced variability of WEC-generated power in combination with energy storage or power management control at each WEC and at the array level will help increase hosting capacity of distribution feeders for this type of variable renewable generation and minimize electric losses. The use of modeling tools to simulate the resource environment, device dynamics, and utility power system response, along with the development of an interface for an array controller can help to reduce risks and risk perception, gain key stakeholder acceptance, and enable developers to design effective and compatible energy plants with arrays of WEC devices. The project will create a publicly accessible numerical modeling framework to empower the wave energy sector to design projects of various scales (from kilowatts to hundreds of megawatt) that are optimized on a plant performance basis and compatible with different power systems and wave conditions. The framework will integrate with WEC-Sim, a wave environment model (SWAN-FUNWAVE), and relevant established electrical analysis tools to model the grid system and interconnection and optimize power output and power management for the WEC array.



Aggregated Reviewer Comments

- This is a very important piece of work and an excellent addition to the WEC-Sim suite. It is critical for the future development of grid-connected WECs and those supplying islanded communities. In these cases, the frequency and power levels in the grid will have a direct impact on the control of the individual WECs and may (under certain cabling arrangements) lead to changes in the performance of the individual WECs as their PTO forces change due to frequency synchronization. It is disappointing that the model is currently only wave to wire when a bi-directional model is needed in reality (see Kiprakis, A., Nambiar, A., Forehand, D., & Wallace, R. (2009).

Modelling Arrays of Wave Energy Converters Connected to Weak Rural Electricity Networks. In Proceedings First International Conference on Sustainable Power Generation and Supply https://doi.org/10.1109/SUPERGEN.2009.5348024). The reviewer was unsure about the extension of the model to energy systems including battery storage, wind, solar, and diesel generation, etc. Such modeling with the connection of a wave farm to a grid is normally done using tools, such as Power World, that model the grid dynamics and provide power quality information and include the effect of frequency on connected generators. Extending the model in this direction is somewhat of a red herring and could be a displacement activity when it would be better to couple the array tool to existing power system tools.

- This is a good project integrating WEC array modeling and power management. The project achieved further development of WEC-Sim numerical modeling code to develop wave-to-wire modeling for WEC arrays and includes energy yield modeling and storage integration to further develop numerical modeling tools for WEC farm design. An advisory board is in place to help steer the project, and a good number of research publications have been developed. The code is made available in the public domain through GitHub and will be a highly valuable resource for project developers.
- This is very consistent with other tools, and it is good to see the grid integration and storage. The reviewer recommended planning for further model coupling with power grid models onshore for further use.
- It would be good to discuss what device developers are learning from the project team's work. The reviewer inquired about the developer questions the project team is addressing.

WEC Design Optimization

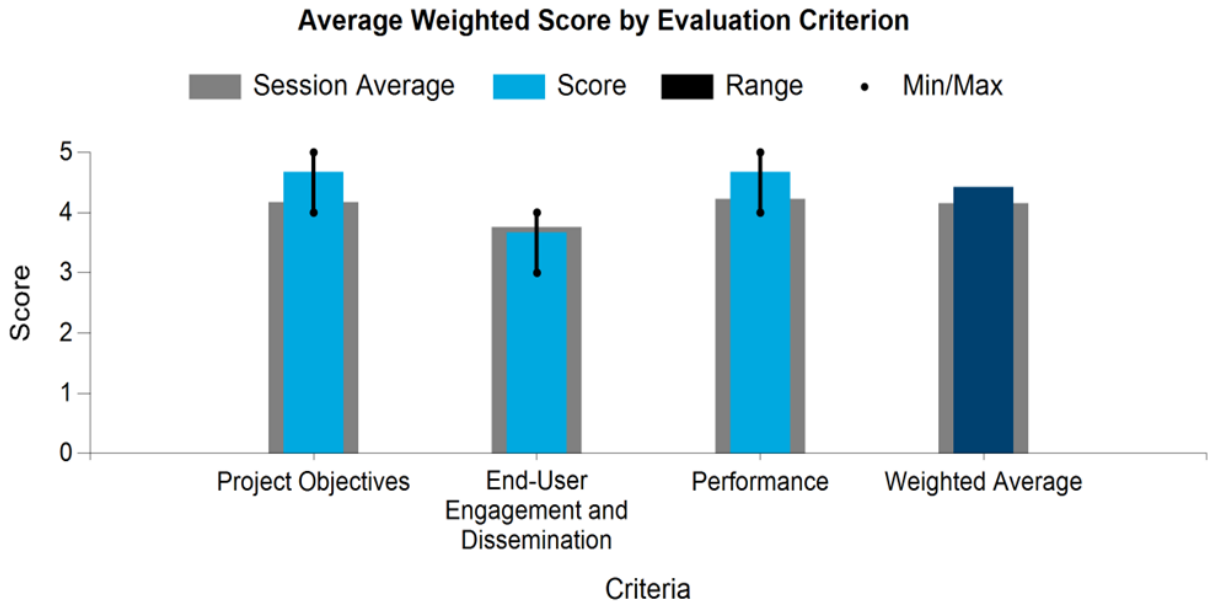
Sandia

WBS:	2.1.3.704
Presenter(s):	Ryan Coe
Project Start Date:	07/01/2018
Planned Project End Date:	09/30/2023

Project Description

For aircraft design, light materials and reliable mechanical systems are critical to a viable design. For wind turbines, longer blades are now being paired with relatively smaller generators to maximize capacity factor. For WECs, these fundamental concepts, which are well understood in other fields, are only beginning to become clear at best. Given the relatively immature nature of WEC design, having a tool with which to perform rapid and holistic design studies is crucial. To address this problem in the past, developers have used brute force approaches, e.g., in which high-dimension matrices of time-domain simulations are run to find the best combination of controller tunings, hull shape, mooring system, PTO components, etc.

WecOptTool has grown out of Sandia's WEC dynamics and controls work as a means of addressing these practical design questions in both internal and industry collaboration projects. A crucial aspect of WecOptTool is the utilization of a pseudo-spectral solution method that efficiently handles nonlinearities, lends itself to a co-design framework, and allows for both unstructured ("numerical optimal") and structured controllers. Written in Python and developed on GitHub, WecOptTool is entirely open-source and free. WecOptTool is already providing direct benefit to industry developers and will continue to deliver deeper insights to a broader audience moving forward.



Aggregated Reviewer Comments

- It is good to see that a tool that complements WEC-Sim has been developed (also using the open-source model) to develop a fast, frequency domain optimizer for the co-design of WECs. Uptake of the software is excellent given that it has only been available for a year. It was also nice to hear that it had been applied to a real device and improvements were identified. The dissemination of the tool is good but could be much better. The reviewer thinks the team has been working with a very small pool of technology developers when working with the wider community would be even more beneficial. The reviewer is certain that there is work on existing

WEC geometries and controllers (which are not under commercial development) that could be used as test cases and would form a strong basis for publicizing and disseminating the tools set. The reviewer also thinks there is a need for stronger interaction with academic researchers, many of whom are looking at novel control systems for WECs and could make excellent use of such an optimization tool.

- This project develops an open-source design tool for WEC optimization and the numerical tool is made available through GitHub. The aims and objectives align well with the program. The results indicate a reliable fast optimization tool that will be very useful for WEC and PTO optimization for developers. Some more information on the validation work would be helpful and on the research, papers published, and dissemination activities planned.
- The project team could give more detail about connections to partners and stakeholder outreach. It is good to have a consistent framework of tools, and the modeling speed increase is laudable. The reviewer inquired about papers published and references.

Wave Energy Converter Interlink Umbilical Cables Design Requirements, Best Practices, and Recommended Design Improvements

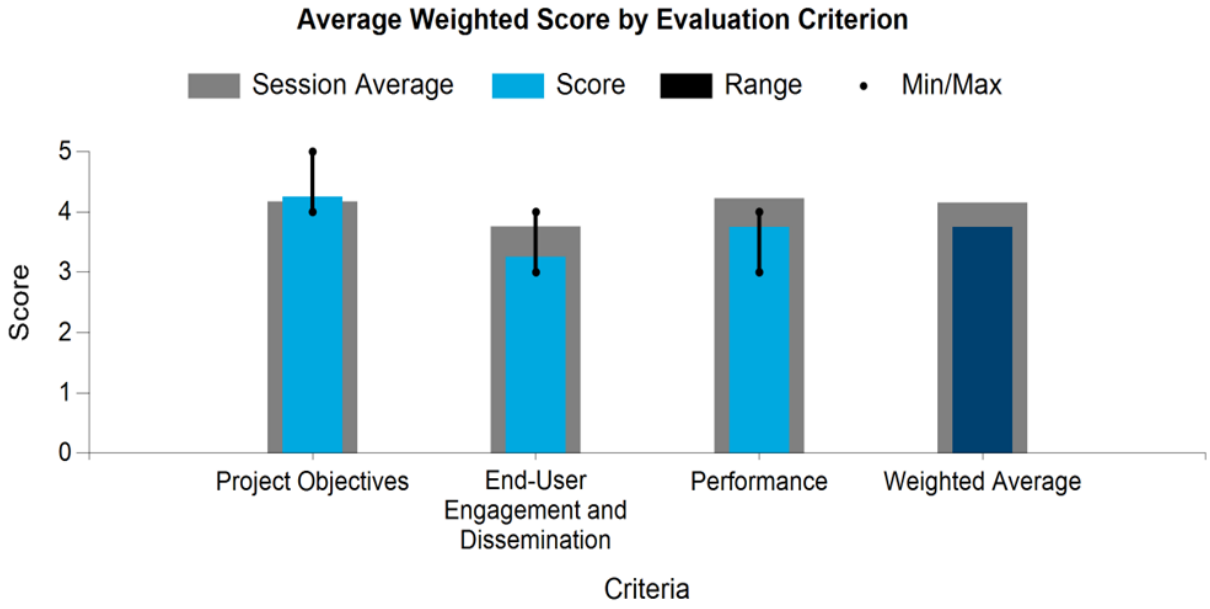
PNNL

WBS:	2.1.4.404
Presenter(s):	Leo Fifield
Project Start Date:	08/01/2018
Planned Project End Date:	09/30/2019

Project Description

This project, led by PNNL and NREL in partnership with offshore cable experts Delmar Systems Inc. and the University of Southampton, aims to accelerate the development and reduce LCOE of commercial wave energy systems by empowering the design and utilization of robust and cost-effective medium-voltage power and communication umbilical cables that connect floating WECs to subsea transmission lines.

This project is utilizing accepted industry practices from offshore wind, oil, and gas and existing software tools (WEC-Sim, OrcaFlex, COMSOL) to evaluate the life-cycle mechanical and electrical performance of interlink umbilical cables, define expected requirements, and make suggested improvements based on techno-economic evaluation. Targeted goals of future work include validation of simulated umbilical cable performance with experimental lab testing and connection with cable manufacturers to advance design, longevity, and WEC cost savings potential.



Aggregated Reviewer Comments

- This project looked at the design of medium-voltage WEC export cables and has developed a multi-physics model to assess cable performance. The results obtained are very important and show that cable designs must account for the motion of the WEC or they will fail very quickly. This work is widely applicable and has implications for WECs, floating MHK turbines, and floating offshore wind systems. The reviewer was surprised the team has been working with a WEC developer and not with a cable manufacturer. A cable manufacturer would have been able to provide an example medium-voltage dynamic cable sample with drawings and support and information on modifications that could be made to cable designs. This would have saved a lot of problems as a DOE-funded project (supported by WPTO) would have a lot more traction with a cable manufacturer than a WEC designer would. If this work is continuing, the reviewer strongly advises getting a cable manufacturer on

board as soon as practicable. There have clearly been issues with the project resulting in experimental tests not being undertaken. This must not detract from the fantastic work done in model development. It would be interesting to see this work extended to included vortex-induced vibration on the dynamic cable (alongside wave-induced motion). Many deployment sites have oceanic- and wind-driven currents that can induce such effects.

- It is a shame that experiments at Southampton were completed due to COVID and delays. The project lacks experiment validation but is otherwise a very good project with engagement with end users and development of a design tool for umbilicals including hydrodynamics, structural response, and electrical performance. Finite element analysis was carried out for the complex cable composite structure. There was good collaboration with WEC developers, but the reviewer recommends that the project team engage with a cable supplier.
- It was unclear to the reviewer whether the presenter mentioned the sources of the cables, and the reviewer asked whether there will be testing with more cables, which would increase the applicability. The reviewer asked if the project team accessed via the WEC or via a cable manufacturer, which would have provided some very different perspective on the cables. (The manufacturer might have said, "Don't use that one. These are better for your purpose.") The reviewer also noted not to dismiss the issue of the sea states versus depth. That said, it is definitely of benefit to do such a thorough, integrative physics project, and it seems this would be of equal benefit to offshore wind installations.
- This project reflects good work overall with good attention to detail. The cable installer and cable user involvement in this work is good but having a cable manufacturer on board would help. The reviewer was unclear on whether the project team considered dynamic coupling between cable oscillations and the magnetic fields generated by current passing through the cable. This could become an issue when converter motions are large and/or there are vortex-induced oscillations that bring parts of the cable closer together than they are meant to be.

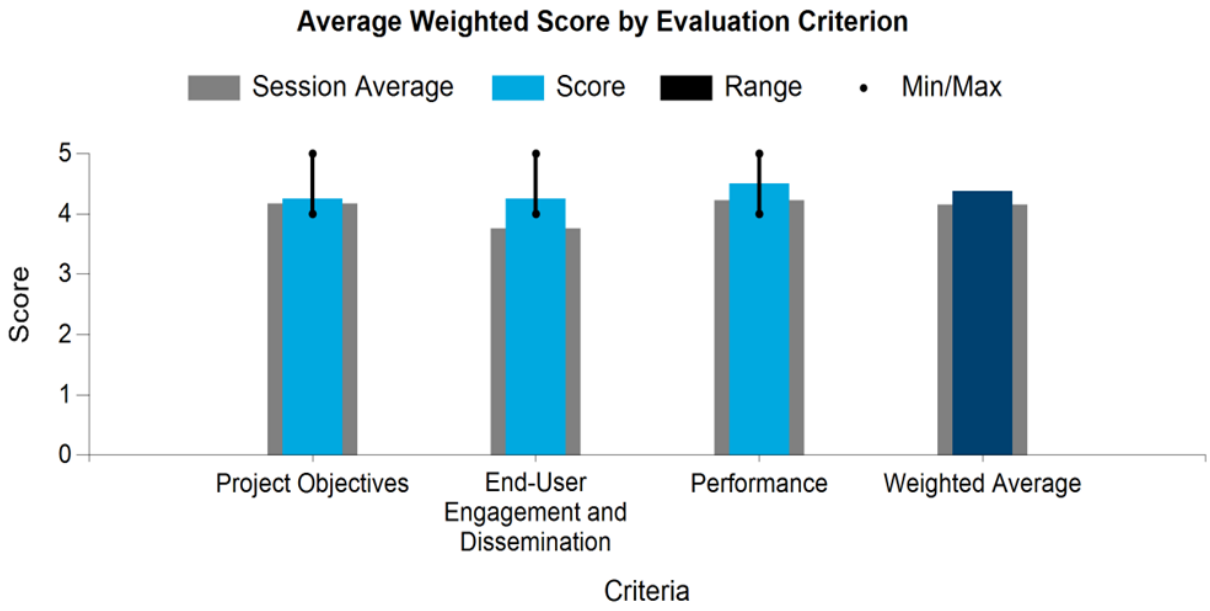
Model Validation and Site Characterization for Early Deployment MHK Sites and Establishment of Wave Classification Scheme

NREL, PNNL, Sandia

WBS:	2.1.5.401
Presenter(s):	Levi Kilcher; Vincent Neary; Zhaoqing Yang
Project Start Date:	10/01/2015
Planned Project End Date:	09/30/2020

Project Description

The Model Validation and Site Characterization for Early Deployment MHK Sites and Establishment of Wave Classification Scheme project, commonly known as the Marine Energy Resource Characterization project, is designed to generate and disseminate resource data needed for marine energy device design and project siting and to quantify the high-level marine energy opportunity for decision makers. The project has been a collaboration between NREL, PNNL, and Sandia since 2016. Without this project, high-quality datasets that can be used to assess resource opportunities would not be available. The project combines the institutional resources of the three labs to deliver coordinated and consistent results that leverage the expertise across the labs. The data the project generates is disseminated in several formats to maximize impact—from the Marine Energy Atlas for the public to cloud-hosted data APIs for researchers who need efficient access to the detailed underlying data.



Aggregated Reviewer Comments

- This resource characterization project is an extremely important piece of work. In particular, the compilation of marine energy atlases within a GIS framework provides an extremely valuable tool for both the assessment of the overall resource potential and the determination of potential sites for deployment. While this work is critical for the wave energy and MHK sectors, it is equally important for offshore wind, particularly floating systems, and for other marine users. The combination of high-resolution, met-ocean modeling and accurate field measurements is of significant value, and it is important that (as is being done) this data is made publicly available. It is clear that the team has worked with developers and the wider community to identify metrics for the marine energy atlas that are meaningful for developers. The ability of the tool to take a power matrix and to provide (omni directional?) estimates of power production is extremely useful. Given that this is built within GIS environment, it would be extremely valuable if the tool set could include other constraint information

(bathymetry, navigational routes, distances to ports, sea-bed slope, exclusion areas, etc.) to allow a multi-criteria site selection to be performed. This was done in Europe by the MARINA Platform project (see Craddena et al (2016) multi-criteria site selection for offshore renewable energy platforms, Renewable Energy, https://doi.org/10.1016/j.renene.2015.10.035) and allowed decisions to be made on the basis of estimated LCOE for different technologies. In tidal energy, the reviewer suggests being careful about simply providing current speed and turbulence intensity. Work in the RealTide project and data from the EMEC tidal site have shown that significant loads on MHK turbines can be created through wave action and that the turbulence is highly anisotropic with very large-scale structures that affect loading. The reviewer is aware measurements made by PNNL at U.S. tidal sites show similar tenancies. Gross simplifications to average turbulence intensity and length scale risk badly misleading developers and causing either very high safety factors or machines that fail quickly. Wave current interactions are also very important for both technologies. This work has also shown that the turbulence spectra used by codes such as TidalBladed and TurbSim, which are essentially marinized wind spectra, are a gross simplification at best and just plain wrong at worst. Consequently, the reviewer is very concerned that there is not enough knowledge to be able to embark on a tidal site classification system of the type proposed. The reviewer has similar concerns for WECs where almost every machine has different characteristics and, consequently, there is not enough knowledge about likely technologies to classify sites in a meaningful way. One final observation is that it is known that the third generation spectral models (WAM3 and WaveWatch3) used in met-ocean codes perform very poorly under certain conditions and cannot account for many non-linear wave interactions that can be important at energetic sites. These models still owe much to the first generation approximations used to estimate wave conditions for the D-Day landings but now have lots and lots of correction factors added into them. The reviewer is certain a discussion with NOAA on open ocean wave modeling would be very instructive.

- This is a large and ambitious project focused on impactful wave resource characterization at commercially promising sites using various data collection campaigns and mapping through a layered GIS model. The project also aims to develop classification of different WEC types for standardization, although this may be premature. The data collected and collated is open-source information and utilizes existing modeling resource and data. This is a hugely valuable dataset that will be well used by the sector in the years to come. The project also includes a capacity factor mapping tool. There is an opportunity to include GIS layers of bathymetry, site characterization, other marine users, ecology etc. There is strong engagement with potential users through webinars and webpages and a significant list of research publications.
- Thank you for the excellent talk; it is good to know this level of planning is occurring. The reviewer is reassured that they are using NOAA wind data to force the wave modeling and appropriate wave/tide models for the high resolutions. The team should be aware that site characteristics may change suddenly and episodically with conditions not contained within the Climate Forecast System Reanalysis historical datasets.
- Excellent work on resource characterization.

Demonstration of an Advanced Multi-Mode Point Absorber for Wave Energy Conversion

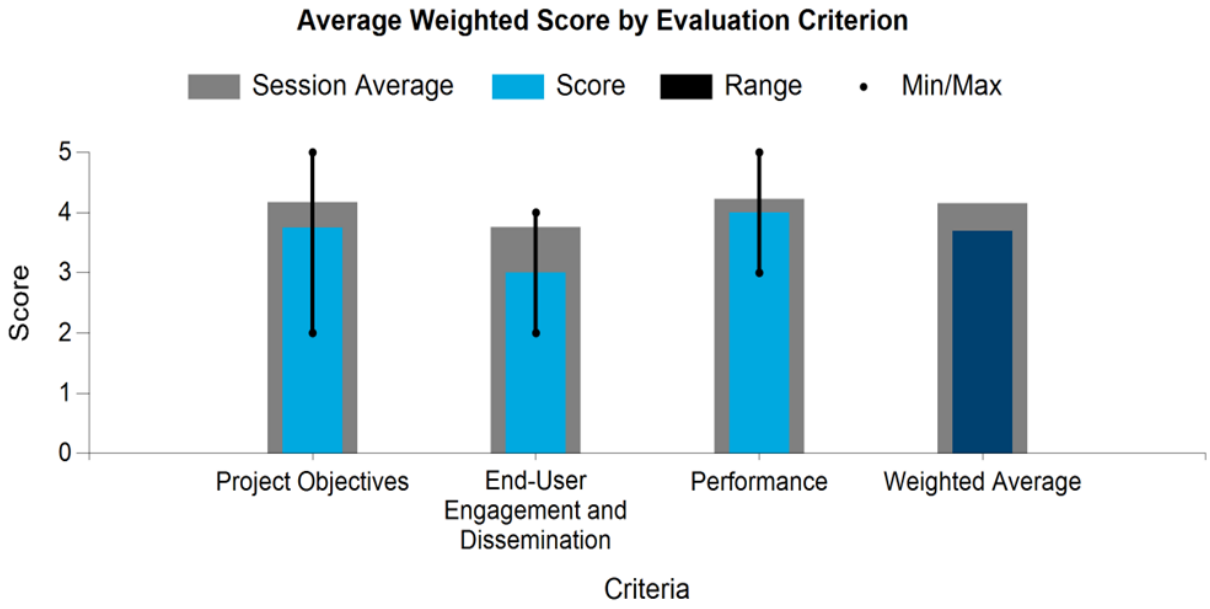
Oscilla Power, Inc.

WBS:	EE0007819
Presenter(s):	Tim Mundon
Project Start Date:	01/01/2017
Planned Project End Date:	09/30/2022

Project Description

The purpose of this project is to design, construct, deploy, and prove the performance of the 100 kW Triton C. The Triton C (for Community) is a two-body, multi-mode WEC that shares the same general architecture as Oscilla's larger 1 MW Triton. At its basic level, the Triton-C comprises a ring-shaped reaction structure that hangs below a surface expression via three tendons. Wave action on the float generates relative motion between these two bodies, which can then be converted to electrical power by the drivetrains. The Triton C was developed with the goal of providing power to remote communities or facilities; however, Oscilla has also seen demand for this system to provide power at sea for high-power PBE applications. The Triton C has been developed with a long travel rotary drivetrain that allows a system of its (relatively) small physical size to operate in fully energetic waves and an improved self-deploying installation approach that allows the system to be deployed quickly and simply with low-cost vessels.

The Triton-C has been constructed and launched and is currently waiting in Honolulu Harbor for the U.S. Navy's WETS to be made ready for its installation. It is provisionally expected to be towed to the site in August 2022 once infrastructure work is complete. When installed, the system will be connected to the Hawaiian Electric Company grid. During its deployment, the Triton-C will also be acting as a testbed to evaluate other technologies and initiatives, such as advanced control techniques developed for Oscilla by Sandia, the Adaptable Environmental Monitoring Platform developed by the University of Washington, and an offshore emergency radio system for the state of Hawaii.



Aggregated Reviewer Comments

- This project has managed to achieve a lot during the COVID pandemic, and the ability to manufacture and ship a prototype WEC to site is a major achievement. The reviewer is concerned that the WEC has remained undeployed, and while this is due to the wave test site not being ready, the reviewer is surprised that the WEC

has been left in the water rather than removed to a laying up area. Being in the water for 12 months without being in operation could lead to significant problems when the device is moved to the test site. Developers working at the one quarter-scale EMEC test sites normally remove their devices from the water in between deployments. Given that this is a foundational R&D project, the reviewer is concerned that their dissemination of project results is rather weak. While this is probably due to a strong commercial focus, it is important that as much general learning from the project as possible is made available to others.

- The project objectives contribute very well to WPTO's mission. The aim is to demonstrate the WEC and novel technologies within it and to take it to commercialization. Good progress has been made, though there are some delays in deployment at the test site, partly COVID related. There is no management plan or risk table in the presentation, and the team should consider how project objectives might be achieved if other delays or issues are experienced. Many issues have been resolved in the construction and a patent granted. Dissemination plans appear limited, and it is not clear what has been shared so far.
- This project might be ready for discussions with specific users to broaden consideration of possible local factors (e.g., size needed, access for repair, and site usage). That would also help motivate a local harbor to be supportive of real-life delays. Harbors have long-term plans they need to accommodate; hopefully, they would be able to help flex calendars if they prioritize this higher. The reviewer was unclear on how this device handles extreme conditions or sudden changes in conditions (e.g., rogue waves and other outliers). It is one thing to show power rating at max, but it would also be beneficial to show expected power rating dependent on sites.
- The team has done a great job under very difficult conditions. The name plate power rating appears to be 100 kW. Absent any discussion of actual conversion performance, it was hard to see how well the device actually performs. The reviewer notes that a point absorber is typically an axisymmetric body that radiates equally in all directions when oscillating in heave. It is also very much smaller than the wavelengths it is designed for.

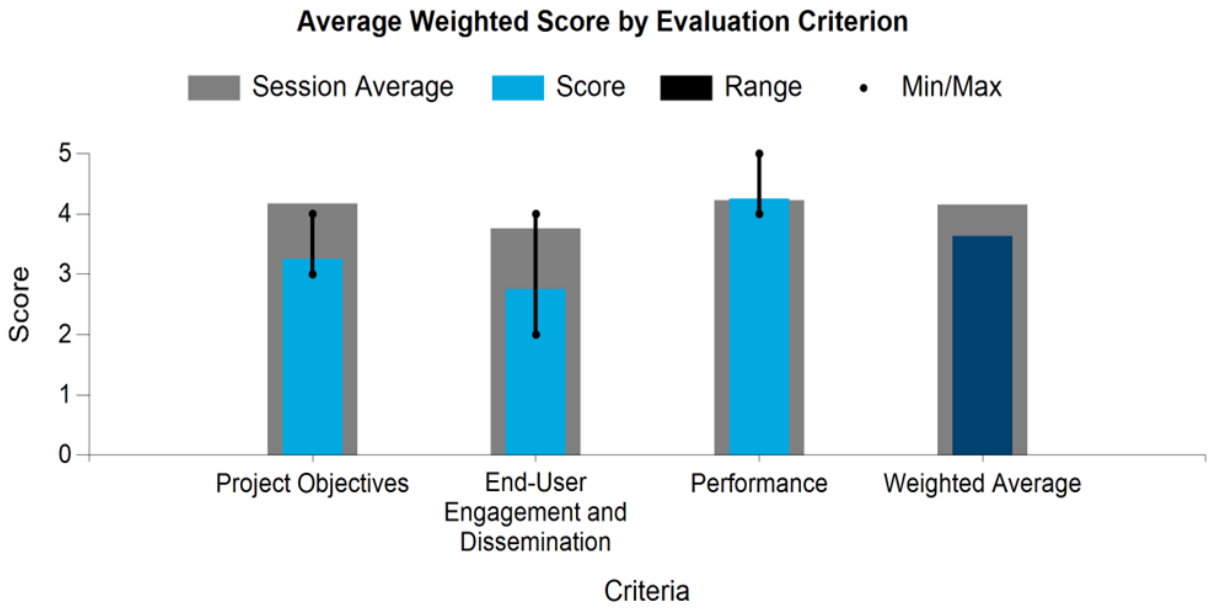
Seawater-Compatible Rotary Pump for Wave Energy Conversion

Resolute Marine Energy, Inc.

WBS:	EE0008385
Presenter(s):	Marcus Gay
Project Start Date:	09/01/2018
Planned Project End Date:	02/28/2022

Project Description

This project aims to design, manufacture, and test a novel, seawater-compatible rotary vane pump to allow for real-time flap modulation in MHK energy systems. This device is necessary to address the end stop issue identified with most PTO architectures for oscillating surge WECs. A scaled pump was manufactured, and a hardwater-in-the-loop system was used to validate the system models for the designed rotary vane pump.



Aggregated Reviewer Comments

- This project has designed and built a prototype for a novel oscillatory salt water pump that delivers the pressures needed to drive a reverse osmosis desalination plant. This is an important achievement and has strong potential to support the provision of potable water for remote communities. This is tightly defined and well executed work on a very interesting idea, and it takes a lot of courage to use seawater as a working fluid. To achieve the full potential of this project, which has a broad range of applications, much stronger dissemination of the results is needed. If dissemination is being held up by a wish to file a patent, then it is disappointing that the patent process was not started early enough to allow proper dissemination. If a patent application is not being made, then I hope a lot of public reports, papers, and public awareness materials are just about to be published.
- This project is complete and awaiting production of its final report. Manufacturing of a prototype double vane pump was successfully achieved, and pump operation within a WEC was tested using a hardware-in-the-loop system. No patents or publications were listed. More details of the plans for dissemination and publication would be useful.
- The brief started with a narrow view of goals/objectives, but should start more broadly and then narrow down to specifics. Reviewers come from a wide variety of backgrounds and this context would help. The pump is designed for one category of users, and the reviewer was unclear on whether there are others who might

become stakeholders. It was stated that the pump is for emergency response, but the reviewer predicts some areas will need this over the long term, which would potentially expand both the stakeholders and design requirements. The discussion of biofouling needs more detail; the response was that this is handled via intake filters/treatment, but those do not keep the microorganisms out, and this pump is dependent on close tolerances of moving parts. The reviewer was unclear on the expected maintenance requirements.

- This appears to be a promising approach to seawater desalination. The reviewer applauds the team's courage in using seawater as the working fluid for their hydraulic system, and other teams would do well to emulate some of these ideas. However, absent a schematic diagram of the overall system, the reviewer can only vaguely visualize the system. Similarly, the reviewer would have appreciated more details on the techno-economic analysis and the mathematical model for the system.

Design of High-Deflection Foils for MHK Applications

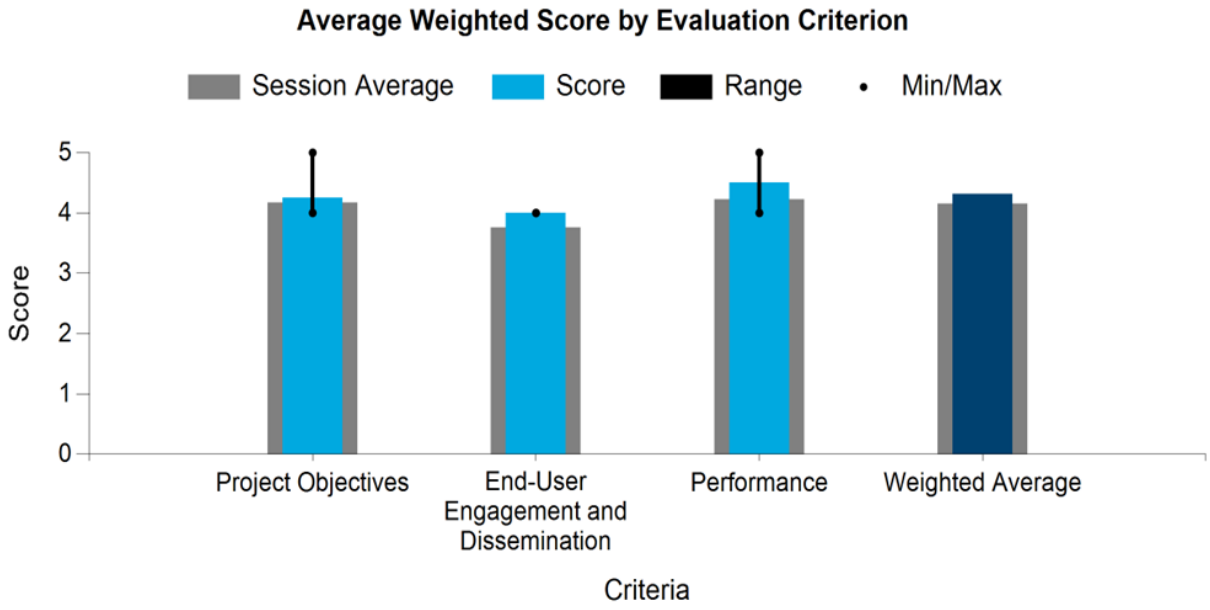
Ocean Renewable Power Company, LLC (ORPC)

WBS:	EE0008386
Presenter(s):	Jarlath McEntee
Project Start Date:	09/01/2018
Planned Project End Date:	12/31/2021

Project Description

This project used model-scale tank testing and fluid-structure-interaction simulations to investigate the behavior of foils with large deflections and the effect of these deflections on crossflow turbine performance with the goal of determining the maximum allowable deflections consonant with efficiency and a robust, durable structure.

A validated modeling and simulation approach was used in the design of an ORPC full-scale turbine. The methodology is applicable to the design of other MHK devices and hydrokinetic turbines that experience significant deflections during operation. Numerous foils exhibiting different deflection behaviors were investigated. The external profile of the test foils was maintained constant, and stiffness of the foils varied using different construction materials. Simulation and validation work focused on developing engineering tools for predicting the effect of high deflection on performance and structural longevity. The tank tests were modeled using computational fluid dynamics and finite element analysis simulations. Methodologies were investigated and refined to allow for load transfer between the computational fluid dynamic and finite element analysis models. A fluid-structure-interaction methodology was validated using the tank test data. Using the analytical methodologies developed in this work, a new high-deflection rotor for ORPC's turbines was designed, making use of the lessons learned in model testing and analytical methods explored in the project.



Aggregated Reviewer Comments

- This is an excellent foundational academic R&D project that has investigated both helical (Gorlov) and straight crossflow turbine designs using a combination of modeling and experimentation (with cross validation). The integration of optical strain measurement systems in the blades delivering continuous strain measurements at a large number of points along the blade is game changing. It was especially good to hear that the resulting datasets will be published on an archival system and provided with a data descriptor in line with best practice

for the publication of large datasets. One issue is that the turbines have been tested in a turbulence-free environment. This is very unrealistic; measurements from real tidal sites and rivers show high levels of turbulence (10% to 20% turbulence intensity) and detailed analysis often shows very large turbulent structures (with length scales exceeding the rotor diameter/blade length) and complex anisotropic flow. Results from the recently concluded European RealTide project have shown that such turbulence is a major driver of loading on blades and is critical when considering fatigue life and control. The reviewer strongly recommends that tests are conducted in flowing water (ideally in a large-scale facility such as FloWave, though an open channel could be used) where the impact of turbulence and perhaps wave loading can be assessed. A further concern is the blockage ratio in the towing tank that has been used. It would be interesting to know how the loadings change and lower blockage ratios (in terms of channel width). This could be achieved using computational fluid dynamic models or by looking at different facilities.

- This project met objectives in generating new knowledge and developing new analysis tools and the study exceeded LCOE projections. This project led to a valuable open-source dataset and student engagement, plus publications at an international conference. The reviewer recommends testing the turbine in a more realistic flow environment to further inform the performance and loading benefits.
- The reviewer reinforced the comment made in discussion about the need for testing to include induced turbulence. The reviewer inquired about whether the tank can handle wave generation. A good first test before going to the field would be no-flow plus waves or controlled-flow plus waves, which could provide some very interesting additions to the dataset. Turbulence/waves will be the norm in any real-use situation.
- The project features an interesting topic and methods, both well summarized in the talk. It was unclear to the reviewer whether scaling up or down involves also scaling structural/material properties. Turbulence effects in real environments need to be accounted for somehow. It was also unclear to the reviewer how people are to interpret and use data for applications at different sites and sizes. The reviewer asked whether this is something to consider for future work.

Performance Testing of an Integrated Magnetic Power Take-Off

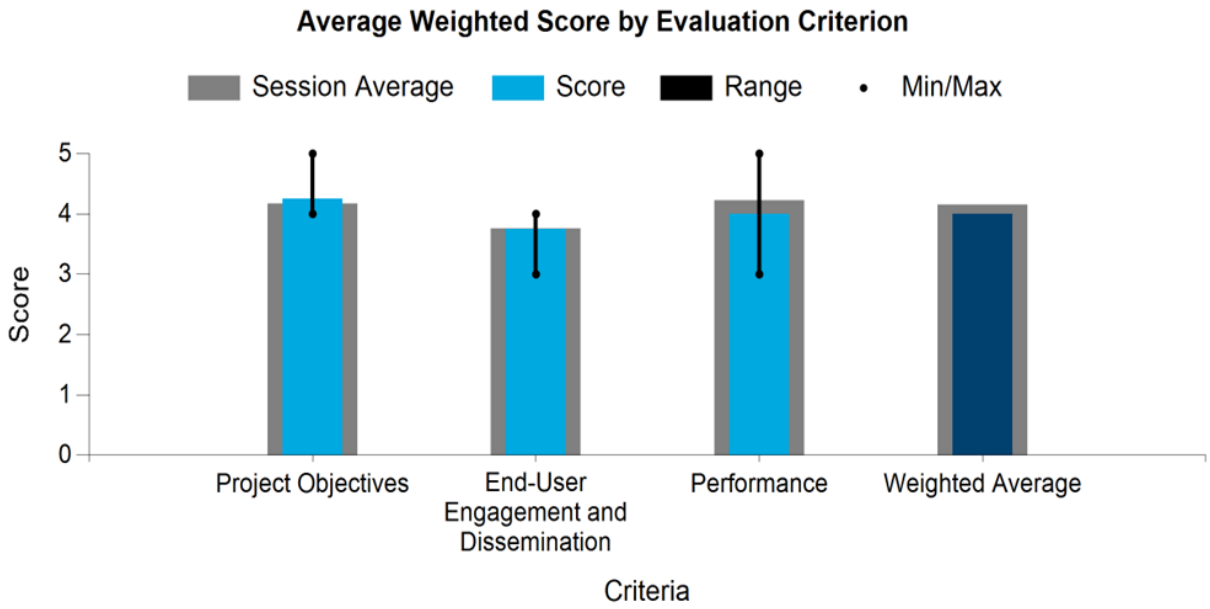
Portland State University

WBS:	EE0008631
Presenter(s):	Jonathan Bird
Project Start Date:	06/01/2019
Planned Project End Date:	06/30/2022

Project Description

The objective of this project is to co-design, fabricate, test, and actively control a new type of rotary magnetic PTO. The magnetic PTO consists of an adjustable stiffness magnetic spring with a magnetic-geared generator. The adjustable stiffness magnetic spring has a linear stroke length with a negative stiffness capability. The project first focused on validating both the rotary and linear stroke length versions of the adjustable stiffness magnetic spring.

By tuning the negative stiffness of the magnetic spring, a WEC can be operated near a resonant state over a wide bandwidth. The magnetic PTO decouples the stiffness and damping needs of the generator system, thereby eliminating the resonant reactive power loading requirement on the generator. This enables smaller WECs to be capable of generating significantly more power. The non-contact magnetic operation should greatly increase reliability and lower maintenance costs. The magnetic torque transfer also provides overload torque protection. At the end of this project, the team seeks to have verified the energy density capability of the adjustable stiffness magnetic spring, demonstrated the potential of a 1/20th-scale magnetic PTO to operate at a resonance condition over a wide bandwidth, and experimentally demonstrated that a magnetic PTO control system can increase the peak-to-average absorbed power ratio by more than 50% over baseline values.



Aggregated Reviewer Comments

- The presentation for this project would have benefited from a much more general introduction and an explanation of the operating principles of the magnetic spring. That said, the reviewer thinks this technology has much broader applications than just in the power train of wave energy devices as there are other applications for adjusting the spring force in this way. Adjustment of the spring force in the control of wave energy devices (and wave makers) has been worked on for a long time and several electro-mechanical systems have been developed (e.g., Salter, S. Wave energy: Nostalgic Ramblings, future hopes and heretical suggestions. J. Ocean Eng. Mar. Energy 2, 399428 (2016). https://doi.org/10.1007/s40722-016-0057-3).

It is important that the adjustable spring force is included into the equations of motion for the WEC and that this is part of the control strategy for the device. Maguire and Ingram ("On Geometric Design Considerations and Control Methodologies for Absorbing Wavemakers," Coastal Engineering, Vol. 58, no. 2, 135-142, 2011. DOI:10.1016/j.coastaleng.2010.09.002.) showed that the absorption efficiency spectrum could be significantly broadened by combining geometric design at one frequency with spring/damper control at a different frequency. This is an area that needs to be investigated by the team and could be done using hardware-in-the-loop bench tests with realistic wave input conditions. The reviewer's final technical concern is that the team plans to perform tests in a wave tank. The reviewer does not understand the need to do this or the benefits of doing so. Subjecting the drive train to realistic, wave-induced motions in a hardware-in-the-loop bench test would be much faster and cheaper and will enable a much broader range of conditions to be examined. The additional complications of building a PTO that can be placed in a WEC and tested in the lab will only muddy the waters. One last point is that it was stressed several times that underrepresented groups of students would be targeted for recruitment. While this is laudable from a diversity and inclusion perspective, no statistics were presented to show that this strategy had had any effect.

- This project achieved its objectives with a prototype built and tested. Results were compared with a finite element analysis numerical model and shown to compare well. A no-cost extension has been granted to the project, and further testing is planned at a national lab with scaled wave conditions in a wave tank. Some delays were due to COVID-19. There was a good level of dissemination and research output with two patents granted and seven research papers published. However, a wider range of applications could be explored.
- It sounds like this effort could assist a broad array of customers. The reviewer inquired whether others been contacted or reached out based on the briefs/publications. It might be beneficial to provide a comparison of the bandwidth resonance shape using this spring. It would have been good to see more of the decision process for the chosen rotary spring and modeling/testing of the choice.
- This is interesting work. The use of magnets to produce a negative spring effect when needed is potentially promising. The reviewer inquired whether the team performed a stability analysis (over a frequency range wide enough to include environmental noise sources) on the whole system with the magnets active. The reviewer also asked whether the team derived the scaling laws for the system and/or performed an energy balance analysis with the magnets active.

Holistic Control Embedded Power Take-Off (PTO) Development

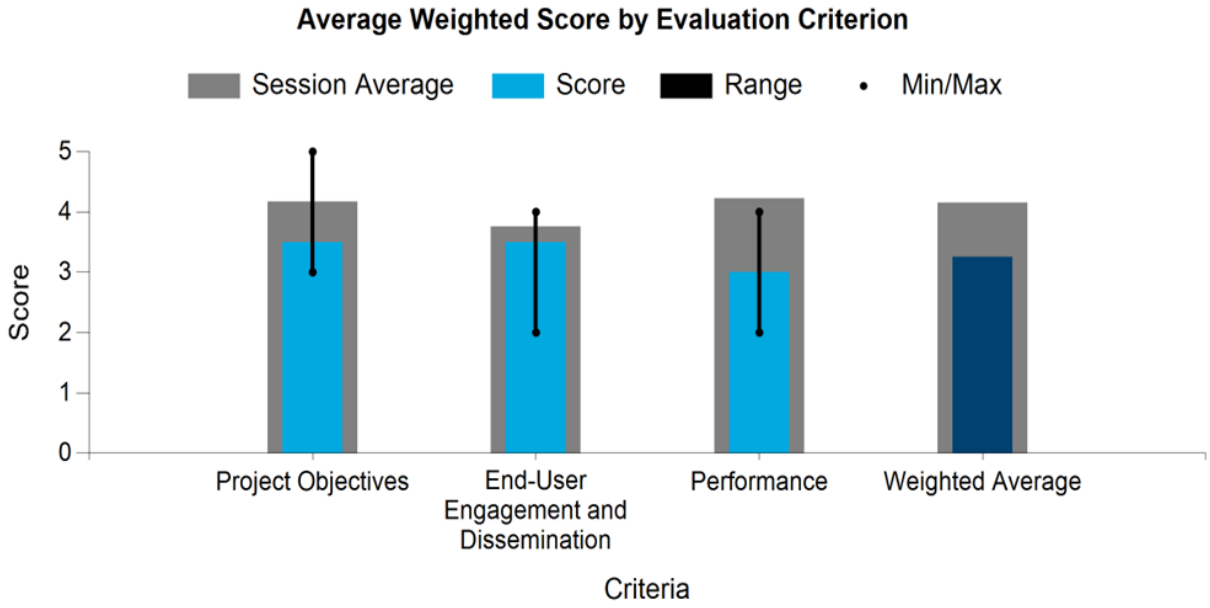
CalWave Power Technologies Inc.

WBS:	EE0008632
Presenter(s):	Marcus Lehmann; Dan Petcovic; Thomas Boerner
Project Start Date:	04/01/2019
Planned Project End Date:	01/31/2022

Project Description

Based on state-of-the-art control strategies for WECs and CalWave's prior development of effective WEC absorber load management strategies, the primary goals of this holistic controls and PTO design project are to inherently couple the design of CalWave's PTO architecture with PTO control design for cost- and performance-efficient PTOs; to further develop a full wave-to-wire simulation, including a precise PTO model coupled with the inherently required PTO control strategy; to integrate primary (absorber geometry) and secondary (PTO) conversion step control strategies into a holistic control framework; and to achieve synergies for lean and efficient design of the PTO in terms of specified PTO metrics (e.g., peak-to-mean force or power).

For demonstration, assessment, and validation of achieving these goals, an advanced PTO system and control architecture will be physically set up and bench tested in a controlled laboratory environment utilizing a real-time, hardware-in-the-loop approach.



Aggregated Reviewer Comments

- This project was one of a number funded by the water power program, and it was not clear to reviewers how the projects were related or what work was conducted under the Holistic Embedded Control PTO project. As the other projects were reviewed by other panels, it would be useful to have a more general overview of the linkages. The reviewer was disappointed that more technical detail on the PTO project was not presented as this makes it very hard to pass a fair judgement. CalWave needs to be congratulated on completing a 10-month deployment off the Scripps Institute pier in California. The review did not understand why field testing is being used to optimize the PTO controller. Such optimizations are normally done based on tank testing and modeling using multidirectional, representative sea conditions. This enables the PTO forces, required damping and spring forces, and aspects of the controller to be designed, hopefully as part of the co-design process discussed by

several of the other Foundational R&D water power program projects under review. This approach is mandatory for developers in both the Wave Energy Scotland and Europe Wave programs and is certainly considered best practice. The approach was taken following the failure of several technology developers that was driven by a rush to "put steel in the water," which is a very expensive way of learning lessons. Working in this back-to-front way seems to have delayed true PTO optimization work while data from the sea trials are analyzed. Surely, the design and operating conditions are known from wave buoy data and met-ocean predictions at the test site. Given that this is a Foundational R&D project, it is unclear how replicable and transferable the results of this project are.

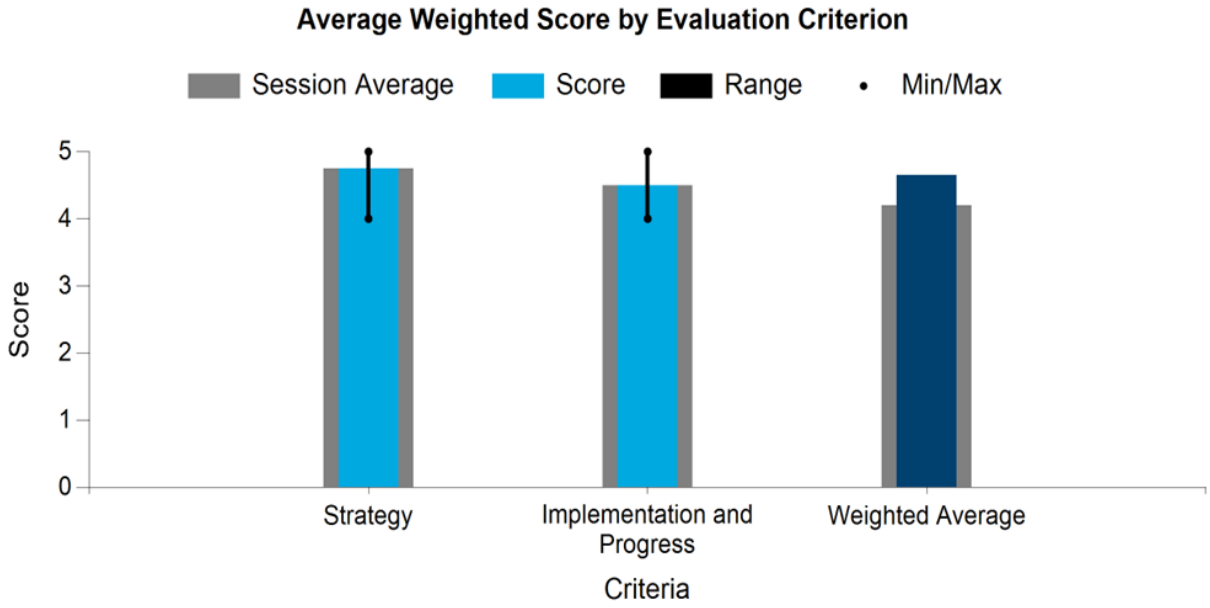
- The relationship of this project to other ongoing projects by the project team should be clarified. There is good dissemination at symposia and workshops. The project is currently underspent due to delays in engaging external partners for the manufacturing step. Modeling and simulation are complete, but design, build, and commissioning and test bench activities are planned for budget period two. Significant budget is allocated to installation and commissioning of the test bench in budget period two.
- This project appears connected to multiple other projects, and it seemed the presentation was primarily about the larger project (or other aspects of the larger project). There seemed to be less about this project. It was unclear to the reviewer how widely compatible this control system would be with other equipment designs. The reviewer also inquired about sea condition limits. This will also impact cable tolerances/choice.
- The reviewer appreciated the presenter's time. It is good to see that the device has been in the water for a long time. In the future, it would help to have an overall schematic of the device and an indication of the geometric shapes and sizes of its components and even of all the mechanical and electrical components involved, particularly because the project title includes terms such as "holistic control."

Technology-Specific System Design and Validation

Activity Area Evaluation

WPTO

WBS:	2.2
Presenter(s):	Elaine Buck



Aggregated Reviewer Comments

- There is an excellent breadth and depth of projects across a range of scales and an excellent range of funding mechanisms available. There are some excellent examples of collaborations between companies, but some projects seem to be running in isolation even when prior knowledge or learning may be of huge value. Enabling and encouraging collaboration and knowledge capture has been of benefit in some projects and would certainly benefit others. It is good to hear WPTO is working with projects to address concerns and challenges rather than sticking rigidly to original plans; this is imperative for achieving the best outcomes, and DOE should be commended for this. It is, of course, vitally important to ensure this remains the case as further challenges are experienced. The reviewer believes it is important to get prototype systems wet ASAP; it is only in real world, at-sea testing where a number of the residual challenges will be discovered. There needs to be a plan in place for funding "updates" to machines following initial deployments to cover the unknown unknowns that will inevitably occur (and could not necessarily be predicted at the beginning of the project). The reviewer recommends some kind of contingency fund (a percent of overall budget perhaps) that is budgeted by DOE and ringfenced at the beginning of the project that can then be accessed during at-sea testing when appropriate rationale is provided. Following on from this, there is a clearly stated goal of kilowatt and megawatt devices, but it is unclear from the information provided how this funding will address the so-called "valley of death" between initial prototype deployment and commercial devices as it is almost guaranteed that support of some kind will still be required. The reviewer thinks it will be important from both a developer's and investor's perspective that there is at least visibility of what funding may or may not be available on the runway through to commercialization. There is a residual concern that in the current environment with budgets getting very tight that the obvious candidate for reduced budget will be O&M activities and equipment that need expenditure toward the end of the project and are often under budgeted anyway. If this occurs, there is equally a concern

that failure to spend properly here can lead to serious health, safety, and environment problems in what is the riskiest part of the project in this regard. This needs close monitoring. Acknowledging this may be due to the assigned projects, the reviewer noted projects predominantly seem to focus on full systems rather than sub-systems or enabling technology. Refining the problem to specific key systems or interfaces may be something worth consideration. It is good to hear a best practices suite of documents is under development; this could be hugely valuable. If it is not already there, the inclusion of a robust work-up program needs to be included in any significant at-sea deployment. (If it can go wrong, it will go wrong. Companies need plans in place for how to deal with that prior to deployment and for gradual exposure of critical system to more energetic conditions.) Also, a work-up program significantly reduces risks during initial deployments and allows on-the-fly validation of critical subsystems before they are really critical.

- The challenges are identified. The reviewer feels that it is missing more emphasis on the design phase. Before the prototype is deployed, there is a need to have a robust design—software, consolidation of analytical methods, good understanding of the safety margins and the limits of the design, etc. There is a need to connect a prototype to improvements in design methodology and identification of degradation and reliability. Standards have to be connected to the lessons learned from the prototype deployments. As there is a multitude of technologies in marine renewables, the learning process will be more complex and more difficult to consolidate on standards. There is a good degree of diversity in the projects. However, some careful considerations should be given to technologies that appear to be based on technologies that have been tried before.
- This is a well-balanced program with good breadth and depth in all areas. There is excellent management of the overall program by committed WPTO staff and leadership. Consideration should be given if the program can sustain its current breadth as its technology's initiatives require more funding and WPTO staff management time as they mature in scale and TRL level.
- This program is very well designed and well planned. The work that has been supported to date is moving the marine energy industry forward, and locations, such as PacWave and the Maine Maritime Academy, offer real-world testing locations that are precisely what industry needs. The support of the companies and the way the WPTO team works with these companies are leading to successes. From the thorough review process to the ongoing support while they are working on projects, the companies have a valuable partner in the work. It is clear from the projects presented that the companies appreciate the opportunities and support they have. This program has been growing for a few years, and the private sector has not been doing its part to "take the ball and run with it." As a result, there is a danger that the companies will have an unpleasant valley of death. It is clear this is a concern for WPTO, and the solution is not clear for anyone. Internationally, there has been some success at getting companies to near commercial, but many companies have collapsed. Given that the private sector has not seen the value yet, it seems that in order to make this technology a viable part of our energy mix going forward, the public sector needs to support it. Internal combustion engines, turbines, nuclear power, and more were fully developed by the military and public sectors before being commercialized. WPTO needs to decide if marine energy is the solution that we all think it can be and, if the office believes it is, then there may need to be full commitment to get the technology to commercial. Overall, WPTO develops comprehensive, clear programs that have achievable goals and push the industry forward while ensuring access and education broadly.

Project Evaluations

Wave-SPARC Structured Innovation

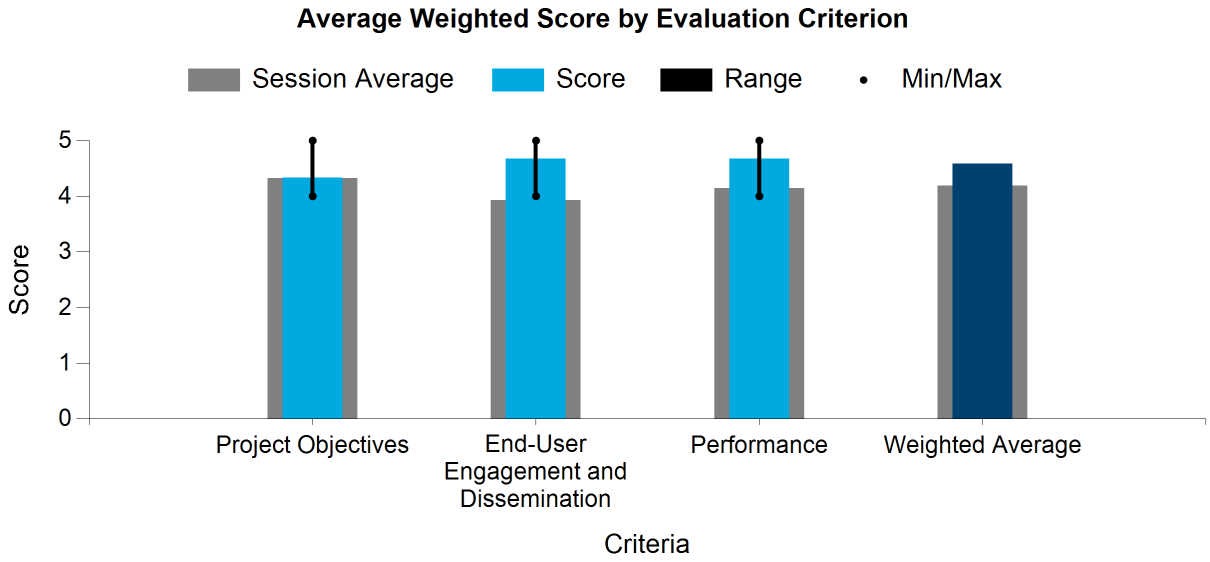
NREL, Sandia

WBS:	2.2.1.402
Presenter(s):	Jochem Weber
Project Start Date:	10/01/2014
Planned Project End Date:	09/30/2024

Project Description

Wave-SPARC is empowering the marine energy community with the tools necessary to achieve a significant improvement in techno-economic performance of wave-generated grid power. A detailed systems engineering approach simultaneously balances around 100 cost and performance drivers (functional requirements and capabilities) of WECs. Publicly accessible technology innovation and assessment methods and tools (new to the wave energy sector) have been delivered. These resources guide technology development trajectories to successful outcomes in less time, at less overall cost, and with less encountered risk. With the use of these methods and tools along with proven and structured inventive techniques, the project continues to deliver high potential novel wave energy technology concepts for validation and subsequent development by industry.

Intended project outcomes include the invention, assessment, identification, verification, and validation of novel and high techno-economic-potential WEC technology concepts to deliver high-confidence "seeds" for subsequent industrial development to full commercial application and economic viability; development and delivery of WEC technology innovation and assessment methodologies and tools and provision of these resources as services available for free to industry and the entire sector; and international collaboration for global best practice alignment of assessment and innovation methods.



Aggregated Reviewer Comments

- The project has an excellent rationale behind it. The PIs understand well where it is useful and where limitations arise. The reviewer liked the comment that the benefit is in the process rather than the output. The reviewer thinks understanding this across the board will be important to more widespread use for development purposes. The long-term project is delivering frequent updates and dissemination. There are multiple use cases that could be valuable (and have been explained), and engagement with potential end users is apparent.
- The objectives are well relevant to the wave sector development. Regarding dissemination and engagement, there is a successful level of involvement of developers, and the project is of interest to all stakeholders. Regarding performance, the outcome of the project is directly related to the use of the process to different stakeholders.
- This is an interesting structured innovation project that is an excellent fit with the WPTO program. The uptake and impact the tool is having on the sector was unclear to the reviewer. There is a good engagement strategy for building the tool, but it is unclear who is actually using the tool. The end-user/industry engagement for the tool's use appears to lacking in this project. This is a very well run and managed project. There seems to be plan to widen its scope; however, it seems a natural next step would be to focus on the uptake and impact of the existing tool.
- This is greatly needed in the industry. It is important that these are living documents that get regular feedback.

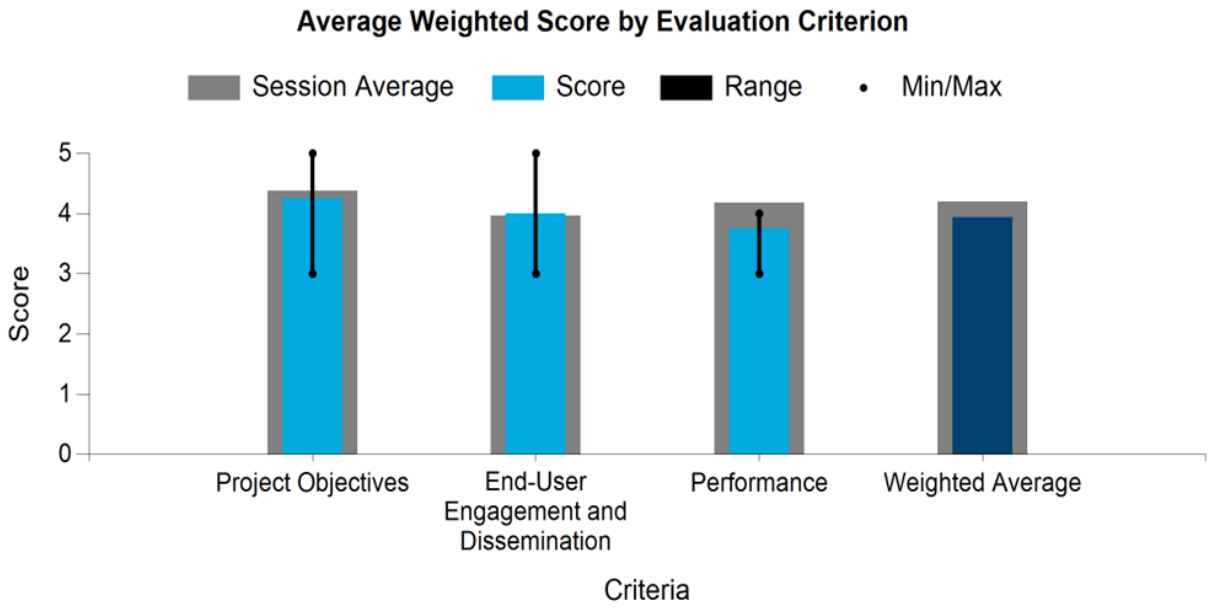
Distributed Embedded Energy Converter Technologies (DEEC-TEC)

NREL

WBS:	2.2.1.407
Presenter(s):	Blake Boren
Project Start Date:	08/01/2018
Planned Project End Date:	03/31/2020

Project Description

Distributed embedded energy converter technologies (DEEC-Tec) could revolutionize how stakeholders conceptualize ocean WECs and view and evaluate the overall viability of ocean waves as a source of renewable energy. However, DEEC-Tec is a nascent and underdeveloped technology domain with a need for in-depth R&D. The overall goals of this project are to advance the scientific and engineering understanding of DEEC-Tec and to study how the DEEC-Tec domain could be best utilized to create effective and viable forms of DEEC-Tec-based WECs (also known as flexWECs). This project will create and disseminate foundational knowledge to empower future research, tool development, and decision making for DEEC-Tec in the marine energy sector.



Aggregated Reviewer Comments

- This disruptive technology is an exciting and worthwhile research avenue that is pertinent for WPTO's longer-term goals for marine energy. However, the reviewer believes this project would sit better within the foundational R&D workstream and, at this early R&D stage of the technology, does not necessarily meet the objective for real-life testing of technology concepts. The reviewer's concern for this project is based on the fact that the focus seems to be primarily on the benefits of flexible WEC technology rather than the limitations that may exist for implementation. (Although the reviewer notes that one of the stated project objectives is to identify bottlenecks for development.) The reviewer notes this because of the comment made stating that the structural base material is a large unknown and without assessment of the full WEC implications and/or identifying the technical challenges that may exist beyond the micro-PTO, full understanding of the potential benefits that could be realized is a challenge. The project plan and methodology seem sound, and the reviewer has no concerns over delivery of useful outputs. Project dissemination is occurring.

- Regarding objectives, distributed embedded energy converters are a very new approach and demand a careful assessment on their potential and possible showstoppers. It is a highly disruptive technology. Constraints on the material scaling up, manufacturing, and sustainability should be identified, and collaboration with possible suppliers and manufacturers is important. There are some developers working with flexible structures but not necessarily with a distributed conversion. Regarding performance, it is an early stage to assess performance, but the elements and plan are in the right direction.
- This is an interesting, disruptive project that is an excellent fit with the WPTO program, but it is not clear how industry can get involved. The end-user/industry engagement for this technology use appears to lacking in this project. This is a very well run and managed project. A plan for considering for this type of disruptive technology could involve Wave-SPARC developing ideas/concepts with industry (could be new entrants), labs supporting industry to prove the concept, and industry taking the technology forward in a specific FOA or prize.
- The project was executed well, and the research was all done. The commercial value of this work to the wider industry is unclear. It is not clear if the team was asked to investigate this by industry. While supporting blue sky research is important, this is very applied research and, therefore, it would be expected that it has an application. The presenter stated that there is a lot of interest from the commercial sector, but it is not clear if that will turn into adoption. It is unclear if the patents will be purchasable by industry or if industry would need to pay for them. If they will not have to pay, then it is not clear why a patent was pursued as publication of the work would have had the same impact.

Significant Cost Reduction Potential for Wave Energy Conversion Devices with Variable Geometry Modules

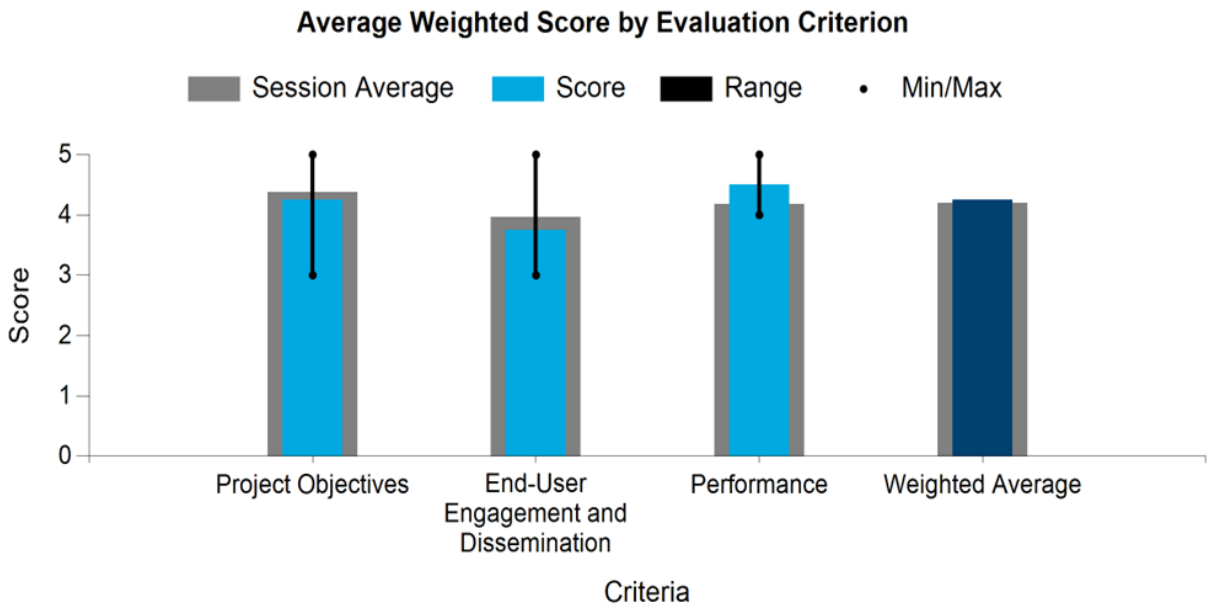
NREL

WBS:	2.2.1.410
Presenter(s):	Nathan Tom
Project Start Date:	06/18/2019
Planned Project End Date:	09/30/2021

Project Description

The Technology Commercialization Fund award is built upon NREL's previous research exploring a bottom-fixed, variable-geometry, oscillating surge wave energy converter (VGOSWEC). However, unlike previous investigations, the VGOSWEC will be raised off the sea floor. Researchers believe that advances in offshore pilings and foundations, such as 3D printing, will provide low-cost and easily deployable structures. There are several benefits to designing a raised VGOSWEC, such as reducing issues with sediment transport and environmental impacts near shore, less expensive deployment and installation as work boats will not risk grounding in shallow water, and deeper water deployments that will improve the wave resource.

The VGOSWEC concept was developed under the assumption that cost reductions and improved system survivability will not be obtained until greater load-shedding capability is designed in the WEC hull. The load shedding capability is enabled through the hydrodynamic control provided by variable-geometry modules. When variable-geometry modules are combined with PTO control, the system can emphasize power production of load shedding. The Technology Commercialization Fund award continued development of the VGOSWEC, adding a raised foundation, to demonstrate the concept is a viable technology that can open a wider range of deployment sites and provide promising cost-of-energy estimates.



Aggregated Reviewer Comments

- Research into variable geometry forms is an interesting potential way to change performance or survivability characteristics of marine energy converters and is an avenue worth exploration for comparative LCOE benefits. Given previous high-profile, flap-type WECs having been developed through to full-scale deployment (with multiple iterations thereof), the reviewer is somewhat uncertain as to the value of this type of project without

specific knowledge that some of it is addressing some/all of the challenges (which, of course, variable geometry might) that have been faced by similar geometry WECs in the past and, therefore, is enhancing the state of the art. If this is the case, then the project would benefit from stating this in some way and make reference back to knowledge capture from previous developers, if possible. This may, of course, have been the case, but this did not come across during the review. The project is disseminating findings and made use of an advisory group. As noted in the presentation, further engagement with the wider marine energy community would also be of benefit. The reviewer's impression is that the project looks at two distinct WEC innovations (variable geometry and raising the WEC). Perhaps distilling these two innovations out and reporting separately on them may be of benefit as they evidently both have different effects and potential effects on the WEC LCOE. The reviewer would have liked to see even comparative value outputs such that the impact of the different innovations can be seen on at least some level (even if not in absolute terms). Without this, it is hard to assess the merit of the projects fully.

- The objectives are clear and focused, but the project seems restricted to this specific technology except if the variable geometry studies can be transferred to other technologies. It seems to the reviewer that raising the flap will increase the energy exposure rather than reducing the loading. The project had limited budget and time for engagement, but it would be interesting to interface with other surge technologies to exchange knowledge and challenges to feed into the project. The reviewer inquired about whether there was any consideration of the PTO restriction or if the results were just for free unrestricted flap. The performance is in line with the objectives of the project. From the information obtained, the next stages would be to look into the implementation. Careful consideration should be given to the mechanisms to change the flap angles as it seems similar to the pitch systems in wind turbines and that is a great source of failures.
- This is a small but interesting wave cost reduction project that is an excellent fit with the WPTO program. They have a well-developed and thought-through plan, and the project appears to be a good value. The project has a good engagement strategy, but industry engagement was lacking. The project has very good technical planning and progress.
- This is valuable work for the sector and a good use of funding. Publication of the work has real value to the industry at large.

Verdant/NREL Research Measurement Campaign

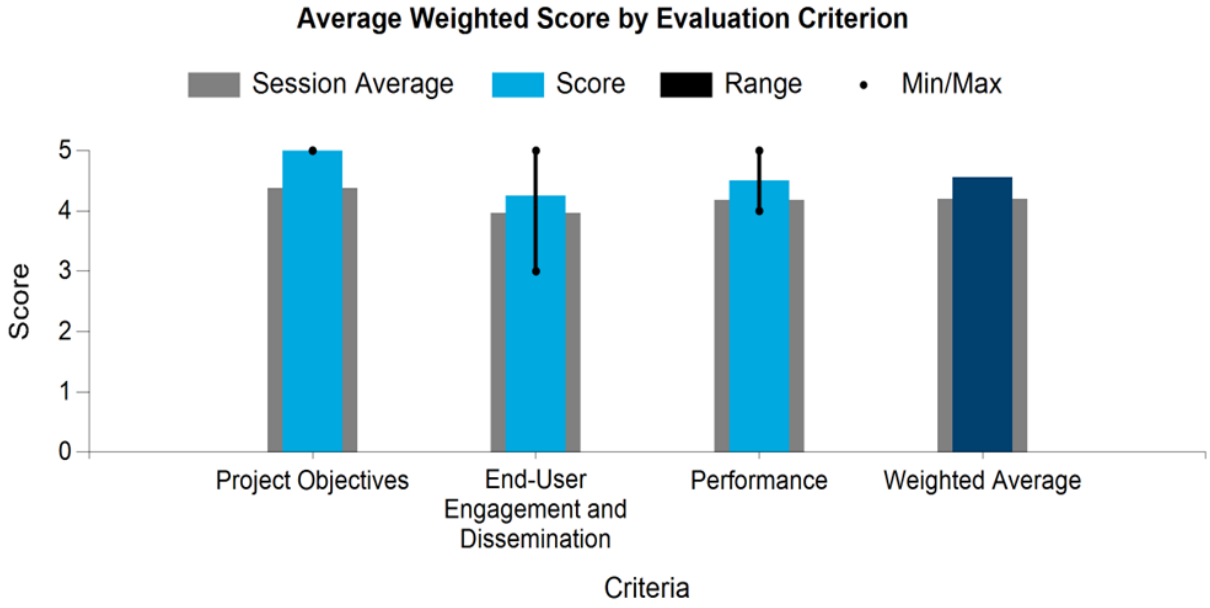
NREL

WBS:	2.2.2.405
Presenter(s):	Robynne Murray
Project Start Date:	08/01/2019
Planned Project End Date:	12/31/2021

Project Description

The marine renewable energy industry primarily uses thermoset composite materials for blades and other hydrodynamic components, which can have up to 50% reduction in strength when exposed to seawater and are not recyclable. Thermoplastic composite materials have been shown at a coupon-scale to have improved seawater saturated properties but have not been validated at full scale.

The primary goal of the project is to demonstrate the structural properties of thermoplastic-fiberglass composite blades compared to epoxy-fiberglass composite blades in seawater at a tidal energy site on an operational turbine. Through this work, NREL manufactured, tested, and deployed thermoplastic blades and a data acquisition system on Verdant Power's turbine TriFrame in the East River in New York City. The thermoplastic blades and data acquisition system were retrieved after a six-month deployment with no signs of degradation, and all cable connections, structural supports, and strain gauges had a 100% survival rate. The blades are currently undergoing post-deployment structural validation to compare their performance to traditional epoxy blades that were deployed for the same amount of time. This will increase confidence in thermoplastic materials and move it closer to commercial adoption as well as increase confidence in the design of a data acquisition system and instrumentation method for a tidal turbine. However, due to an error in the data acquisition system software that was introduced after the data acquisition system and software were validated, no loads data were collected during the deployment.



Aggregated Reviewer Comments

- This is an excellent, well thought out project with clear objectives, a sound scientific approach, and a potentially very usable output in the near term. It is a great example of collaboration between industry and academia to further knowledge in a specific field. The specificity of the project makes results very tangible and immediately useful. The reviewer's only reason for not giving a five for performance is due to the issue with the data capture

system; all other aspects of the project appear to have been run and managed very well. The project was a better value for the money due to the use of data previously available from Verdant Power.

- Regarding objectives, new material requires data and testing in as real conditions as possible. This seems to be achieved here. Regarding performance, a material qualification and design guide on the design and manufacturing for the new material is essential. Testing of the saturated water in the lab to define the ultimate capacity of the blade after the life-cycle dynamic loading had been applied is important. Failure of software has hindered the objectives of the project, but the final tests of the blades will be valuable. Dissemination is still to be performed, but it is important to see how information can be disseminated to the industry without compromising any of Verdant's proprietary information. The project plan was designed to cover all aspects reducing the limitation with data/test results to reduce uncertainties. The score is just impacted by the software failure and the dissemination that basically has not really happened yet.
- This is an interesting blade project that is an excellent fit with the WPTO program. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment to avoid the software issue they had. It was believed their end-user engagement strategy could be expanded to the blade manufacturers supply chain. Although there were some software issues, this was a well-managed project with good results.
- This was a great project. The focused direction and involvement of the industry partner was very positive. The work was tangible and clear, and the results can be applied widely. The industry partner appeared to be very happy with the working relationship. The results benefit widely, so it would be worthwhile spending time doing a deep dive on the reasons the industry partner was happy so that can be translated to future work.

Ocean Observing Prize

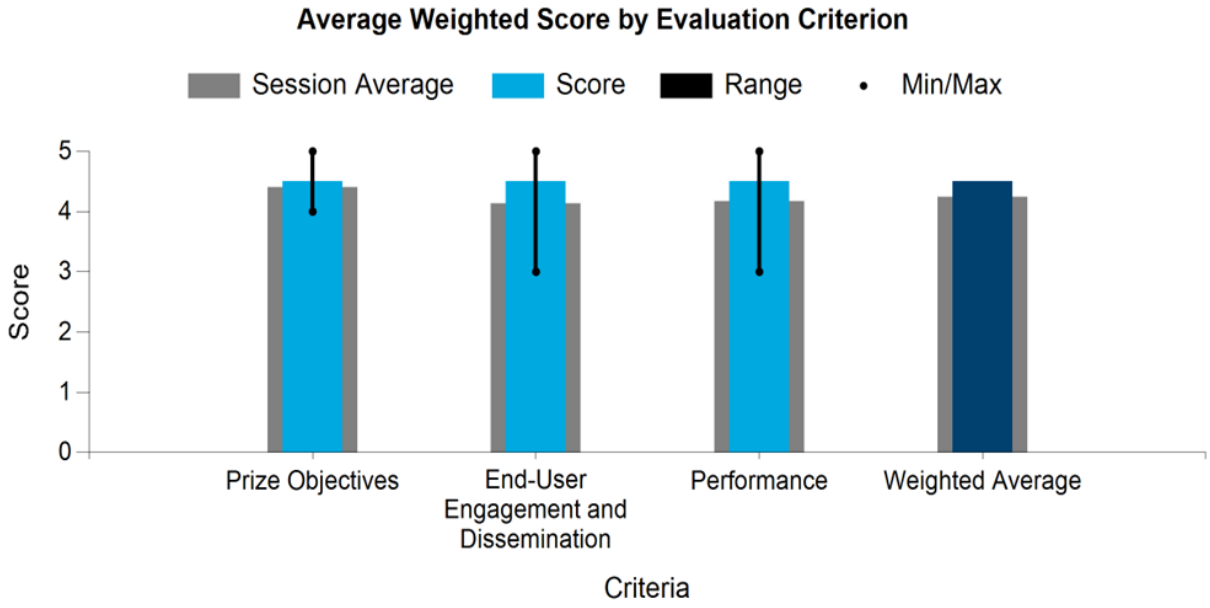
NREL, WPTO

WBS:	2.2.5.401
Presenter(s):	Jenny Wiegele; Carrie Schmaus
Project Start Date:	08/01/2019
Planned Project End Date:	09/30/2022

Project Description

The Powering the Blue Economy™: Ocean Observing Prize is a $2.4 million contest that challenges innovators to develop solutions that integrate marine renewable energy with ocean observation platforms to revolutionize the ability to monitor, manage, and understand the ocean. Competitors are challenged to design, build, and test novel, wave-powered, self-charging autonomous underwater vehicle systems that could be suitable for a six-month deployment in the Atlantic Ocean to monitor hurricane formation.

Through engagement with the end-user ocean observing community, the team identified challenges in a lack of data on storm intensity, endangering coastal communities. This challenge could be addressed by collecting data before, during, and after a hurricane develops and strengthens at sea. Amassing this data, however, requires an ocean observing system that can be deployed at sea for long periods, waiting for approaching storms. To help solve this problem, competitors are working to integrate wave energy capture with autonomous underwater vehicle systems to collect this data, helping to better protect coastal communities from oncoming storms. Solutions developed through this prize aim to enable long-term collection of data before, during, and after a hurricane that will help better forecast storm intensity. The prize mechanism provides an environment to accelerate technology development for innovators and helps to improve awareness of marine energy and its ability to provide power to blue economy applications.



Aggregated Reviewer Comments

- It was interesting to note the comment regarding the prize challenge potentially being too complicated for the purposes of the prize (and this is the reason for the lower score for performance because the outputs are not at as high a level as would have been desirable). The reviewer wondered if, given that wave energy technology is being developed elsewhere within this project, a prize like this would work better if it focused on the more specific problem of WEC-autonomous underwater vehicle interface/energy storage rather than the full problem. Perhaps a WEC (or set of WECs) and the autonomous underwater vehicle could be pre-selected,

and then it is the interface and energy storage/connection challenge that is being sought. These kinds of enabling technologies will be critical to onward development and are a great entry point into the industry for multiple companies without having to dive into full WEC development. There are lots of opportunities for similar enabling technologies—connection systems, umbilicals, elements of mooring systems, etc.—external to the WEC, within the WEC such as specific sensor systems, and other ancillary systems such as maintenance platforms and seals. It would be really interesting to see what WEC developers and people in the industry would like to see developed and perhaps put that out as a prize for some really concentrated development.

- Regarding objectives, it seems there are clear objectives focusing on the critical issues. It was unclear to the reviewer how the WECs will perform in conditions that they normally are not operating in. The reviewer was not sure if a cost target is also part of the prize considerations. Engagement and dissemination seem very successful. It was good to see long-term benefits and a continuation with prize 2.0. Regarding performance, the project seems to be on the right path to achieve the objectives.
- This project has strong relevance to WPTO's program goals. This team worked to incentivize technology development around end-user needs, encouraged engagement from a range of participants, and set up and accessed formal stakeholder advisory groups. The project provided details that showed good use of the funding that was provided to include their distinct focus on creating low barriers to entry and putting in place the structure to strengthen ties between marine energy and ocean observation communities across agencies and in the private sector. The team showcased evidence of advancing marine energy in the blue economy. Their list of outputs was impressive, including communications, community engagement, commercialization support, and one-on-one mentorship. The team showcased a forward-thinking approach and was able to articulate lessons learned that would impact how they could deliver a future project. The reviewer asked the team what it would do radically differently if they were to receive the same amount of funding for another similar activity. They were prepared with an answer and provided details that this was a question they have already considered. The reviewer values the approach they took. It suggests that they were looking to maximize taxpayer funding and adjust the structure of the activity to provide more mentoring and hands-on support to work through the challenges.
- This is an interesting ocean observing wave prize project that is an excellent fit with the WPTO program. They have a well-developed and thought-through plan, but there could be more attention as to how lessons from the prize are transferred to the general wave energy sector. There was good transfer of lessons learned from the desal prize team. There was an excellent engagement strategy and engagement with prize participants and end users.
- This is quite a challenging project for the team. It would have helped the review if there was a sense of the performance metrics that are being pursued. Perhaps later in the project, this information could be presented so that reviewers can gauge the success of the final deployed technology. It would also be helpful to have additional information on the aspects of the project that pertain to the earth observation tools and technologies. This information was not very well presented in the materials. Finally, the team should continue to build partnerships and relationships that will move the project along, especially those organizations and communities that would benefit from the technology should it be successful. These partnerships should go beyond the outreach aspects of the project.
- This prize was an excellent way to introduce marine energy to a wider audience. The program was executed very well with respect to the goals. The blending of ocean sciences and the engineering progress in marine energy are very positive. It would be exciting to see this prize run in a way that it could use the expertise developed by successful WPTO marine energy projects through pairing companies or other ideas the team can come up with. It would be valuable to understand more on how the competition was advertised. This is a challenge and metrics on what media were more successful would be interesting. The reviewer recommends finding a way to get a Netflix or Apple type of organization on board to document or film the work in future prizes, and maybe that could fund the next one.

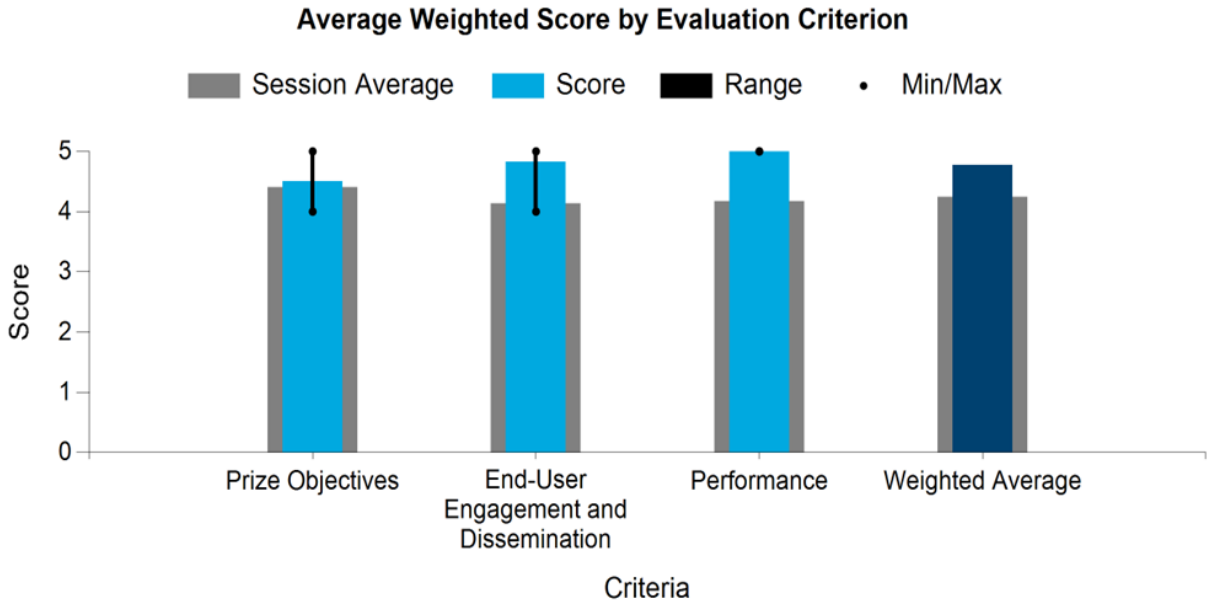
Waves to Water: Desalination Prize

NREL, WPTO

WBS:	2.2.6.401
Presenter(s):	Scott Jenne; Simon Gore
Project Start Date:	01/01/2019
Planned Project End Date:	09/30/2022

Project Description

The Waves to Water Prize was launched in 2019 with the purpose of creating solutions to pair wave energy power with desalination with a specific focus on remote and islanded communities. The Waves to Water Prize administered $3.3 million in prizes over five stages to accelerate the development of small, modular, wave-powered desalination systems capable of providing potable drinking water in disaster-relief scenarios and remote coastal locations. The prize supported the integration of existing and novel wave energy generation technologies with water technologies that can deliver effective, consistent, durable, and low-maintenance water delivery systems.



Aggregated Reviewer Comments

- The positivity and optimism of the presenter was really engaging and got the reviewer excited about this prize. The reviewer liked the fact that learnings surrounding metrics from previous prizes were incorporated. This is an important observation that has relevance in other areas, too. The prize is evidently an excellent way to bring new people and companies into the industry and get them involved as well as to engage the public and gain a wider audience. It is great that the prize is being used to identify future funding and research priorities. It will be important to ensure onward engagement by prize competitors, and the reviewer expects that all finalists had certain advantages and challenges. The reviewer inquired whether there would be any scope for some collaboration of outputs into the state-of-the-art solution. The project adapted well to COVID challenges (with the addition of the ADAPT phase).
- Prizes can promote very positive focus and attention but need careful definition of metrics to avoid distorting complex issues and minimizing important aspects. It is also important not to de-motivate some of the participants and technologies that did not reach the prize but could have some promising technologies. The reviewer inquired how cooperation is handled and incentivized in this case. The project was successful in

engaging participants and the general public. The project was successful considering the objectives, especially regarding the dissemination and engagement with a wider audience. The reviewer inquired about what comes next and how to leverage the project results.

- This team put in place the pieces for a successful project. They reported details of a strong effort to de-risk the project and reduce the barriers to entry to stimulate participation. The project supports WPTO's overall strategy and represents a prize scenario that supports the PBE theme. There is clear evidence that the team has leveraged lessons learned from the Wave Energy Prize, as well as desalination R&D at NREL. The reviewer appreciated the scalability of the program. The presentation showcased the fact that the Wave Energy Prize was the first time many in the audience had seen wave energy as a form of renewable energy. Public engagement efforts were noteworthy and effective in building public awareness on this issue (and included a comic book, numerous public-facing events, etc.). The team highlighted many public-facing events and joint efforts with partner organizations to communicate the effort, purposefully created an event that was fully accessible to the public, and worked to create an environment where people can draw positive conclusions. It is a good move for scientists to bring in a lot of communications folks and program activities that engage audiences. The reviewer appreciated the fact that lessons learned were being documented, leveraged, and shared. The four technologies that they demonstrated produced drinkable water. This fact contributed to the success of the activity and validated their selection of winners. The project relied on numerous partnerships and positioned the model they used as being supportive of a future R&D platform.
- This is an interesting desal wave prize project that is an excellent fit with the WPTO program. They have a well-developed and thought-through plan, but there could be more attention to how lessons from the prize are transferred to the general wave energy sector. There was an excellent engagement strategy and engagement with prize participants. End-user engagement was less clear. There had been some supply chain issues with national instruments, which are out with their control. It was difficult to assess the actual progress and performance of the project. A plan on how to take the winning technologies forward, if appropriate, will be required.
- This project was well designed and took appropriate risks given the early stage of research. The partnerships formed throughout the project were quite notable and important to project success. The presentation did not include much information on commercialization, but it might be too early stage.
- The prize is a great outreach tool. The creativity in all aspects of this project is wonderful. The focus on the application of the technology is a very good way to help the general public understand the opportunity of marine energy. It seems that, as a tool for engaging people in marine energy, this is very effective. It would benefit greatly from industry participation. Military industrial companies would have a vested interest in small-scale desalination solutions as do many municipal governments. It would be interesting to get the end users directly involved in this prize from the beginning.

Reduction of System Cost Characteristics through Innovative Solutions to Installation, Operations, and Maintenance

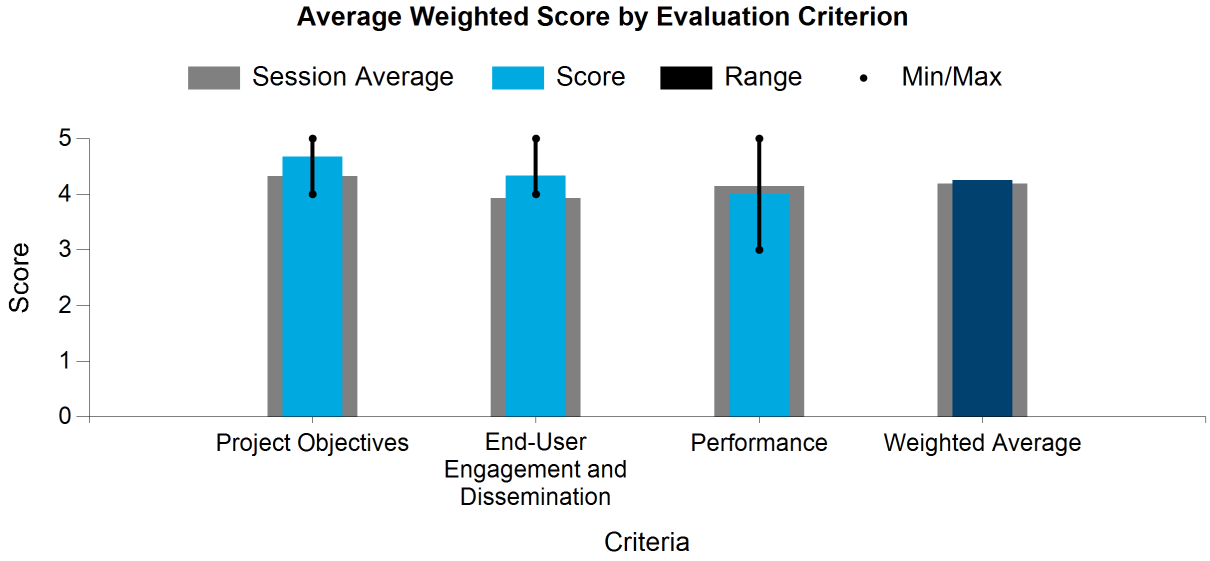
Columbia Power Technologies, Inc. (C-Power)

WBS:	EE0007347
Presenter(s):	Michael Ondusko
Project Start Date:	05/06/2016
Planned Project End Date:	09/30/2022

Project Description

The project designs, builds, and tests the largest practical version of C-Power's SeaRAY low-power WEC architecture that provides an easily transportable and deployable marine power source. The project was revised from the original utility-scale objective to ensure the project-targeted WEC was appropriately matched to available infrastructure and to best leverage mutual investment by DOE and C-Power. Importantly, this WEC completes C-Power's portfolio of low-power, high power-to-weight ratio systems demanded by remote marine power and data customers.

The project is driven by commercial customer requirements in actual applications. The k20 is the subject of multiple commercially funded feasibility studies to evaluate suitability to customer applications globally. The novel mooring design accommodates both shallow and non-shallow locations with a reduced watch circle. This project will demonstrate the integration of commercially available components, such as generators developed for the electric vehicle industry and fuel cells developed for the material handling industry. To demonstrate readiness for blue economy applications, the k20's onboard fuel cell, a novel WEC component, ensures power is available when demanded and has onboard hydrogen storage sufficient to provide well over a megawatt-hour of power.



Aggregated Reviewer Comments

- This project focused on PBE. It has a sensible plan and defined approach. The reviewer liked that this builds on the experience of previous projects and adapts designs and learnings from them. Learnings from this project will also be equally valuable for larger-scale WECs under development. There is clear and obvious engagement with potential end users with commercial partnerships developing. The reviewer liked the mention of iterative risk assessments in the presentation. Among other comments, this gives a level of confidence that a robust design process is being followed. One of the project's stated aims is minimization of IO&M costs, which aligns

well with WPTO objectives. There has clearly been a focus on transportation practicality and efficiency (an excellent outcome) as well as effort focused on offshore operations. There was an interesting comment that one of the major lessons learned from the project so far is familiarity with what is out there. This demonstrates that effort is going into searching for technology transfer opportunities. The reviewer expects this is happening, but there is a need to ensure that any technology being transferred from other industries is a fit for the purpose through lab testing, if possible, prior to deployment. The WEC developer is always the best party to understand the challenges of their particular load regimes and environment, and this may not be obvious to engineers in other industries. Close collaboration with the supply chain is imperative.

- The extent of technology transfer seems to be limited by intellectual property and commercial issues. The performance aspects seem to be on track with the objectives of the project.
- This is an interesting project that is an excellent fit with the WPTO program, although there is a lack of clarity on how meaningful the results will be. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment. It was believed their end-user engagement strategy and engagement with the user and their specific requirements could be improved. Although there had been some supply chain issues with national instruments, which are out with their control, it was difficult to assess the actual progress and performance of the project.
- The project is well executed. It was interesting to hear the presenter discuss the changes to the design and learning that came from this work. Given the supply chain and COVID impacts on technical work in general, this project has been very successful. The scaling from 2 kW to 20 kW is encouraging. Using the 20 kW in very challenging or deep environments will be very costly. It will be interesting to see if there is a customer for this version of the system. The addition of the fuel cell is interesting but raises questions about over-complicating the system with additional technology that is also in development. It would be valuable to understand the power quality and how it conforms to the IEC's 62600. It is dissipated into the seabed currently, and it is not clear if the generated power would need to be held in a battery or could be sent directly to the grid. Power connection would be a good next step. It is important to start using the systems that have been developed. Hours on the system are needed to convince the investment community of the value of the system. The involvement in the project of customers and many project partners is very positive.

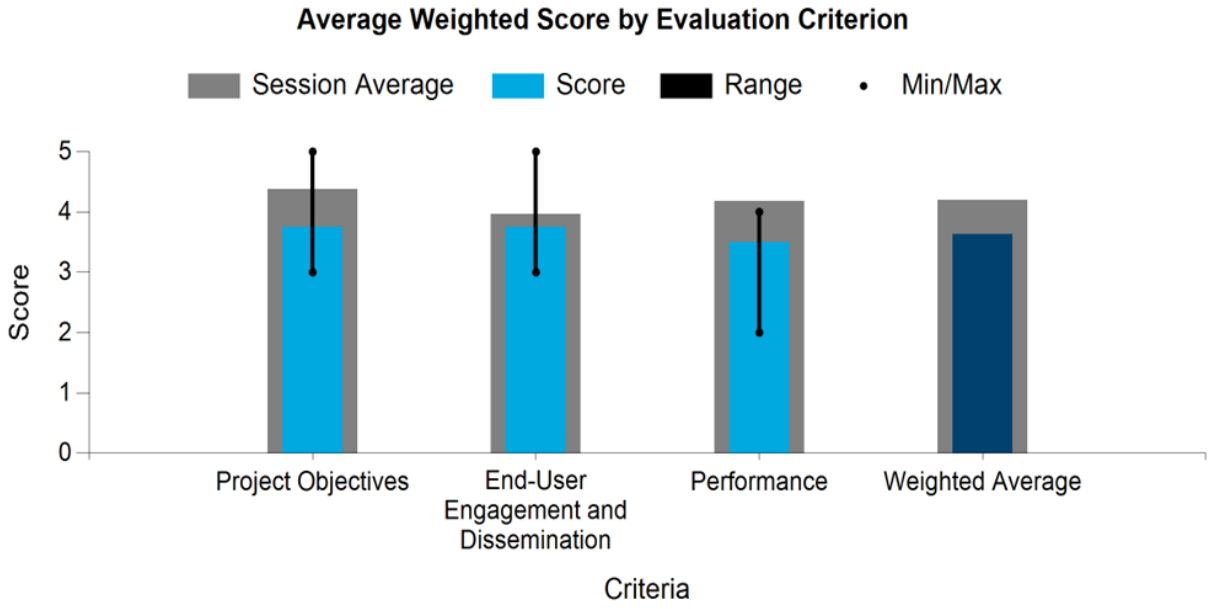
Open Water Testing of a Scaled Next-Generation Point Absorber Wave Energy Device with Phase Control

AquaHarmonics, Inc.

WBS:	EE0008098
Presenter(s):	Alex Hagmuller
Project Start Date:	09/01/2017
Planned Project End Date:	11/30/2022

Project Description

AquaHarmonics began as a concept WEC device to compete in DOE's Wave Energy Prize. The device was designed and manufactured out of a residential office and garage located in southeast Portland, Oregon. The device outperformed 92 other contestants in the prize when it achieved an ACE metric score (which is the ratio of the average climate capture width to the characteristic capital expenditure) of 7.6, a five-time economic improvement over previous state-of-the-art devices, and won $1.5 million. The AquaHarmonics WEC is a floating buoy that is anchored to the sea floor by a single cable. The WEC PTO is unique in the field in that it can provide reactive power in a precise way that allows the WEC to be resonant in a broad range of sea states, which allows for two to three times the power capture of similar-size devices.



Aggregated Reviewer Comments

- The project has evidently faced numerous challenges, and the company has been working through these as they arise. Closer collaboration with suppliers on requirements may be of benefit during procurement to avoid misunderstandings. The project does address WPTO objectives; in some cases there are stronger associations than others. For example, development of human-machine interfaces and controllers is imperative and does address part of the stated objective, but it was not clear to the reviewer that any real thought had been given to safe and efficient offshore operations, which will be a key consideration for deployment and may necessitate design alterations to achieve. More generally, full understanding of through-life requirements of the wider project (e.g., offshore operations, grid connection, and decommissioning) at the outset is necessary for efficient design. Understandably, the project appears to have initially focused on the WEC, but meeting wider requirements appears to have already caused challenges (e.g., grid connectivity) and ensuring these are understood would be valuable. The project's end-user engagement could have been greater. Market

opportunities have been identified, but it is unclear if detailed understanding of these markets or any significant engagement with potential customers has been gained.

- The de-risking at the Sandia Wave Energy PTO Lab is a good strategy, although the incident with a lightning storm was a setback. (Anyway, a new risk to consider and mitigate.) There were several actions and adaptations that the project needed to go through, but that has been a good learning process. The transfer of technology from Space X is interesting considering the impact on LCOE of this different supply sector. The performance aspect seems to be going in the right direction.
- This is an interesting PBE project that is an excellent fit with the WPTO program, although there is a lack of clarity on how meaningful the results will be. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment. It was believed their end-user engagement strategy and engagement with the user and their specific requirements could be significantly improved. Although there had been some supply chain issues, which are out with their control, it was difficult to assess the actual progress and performance of the project.
- It is not clear why the system needed a custom-designed motor generator. This kind of decision leads to concerns that the team is unable to control the boundaries of what needs to be accomplished in the project. The mandate was to build a WEC, yet the team appears to have spent significant funds and time on this motor, which really should have been purchased off the shelf or dealt with in another project. The design and build is an accomplishment, and the test results are a substantial contribution to the state of the art.

Water Horse Hydroelectric Harvester Development

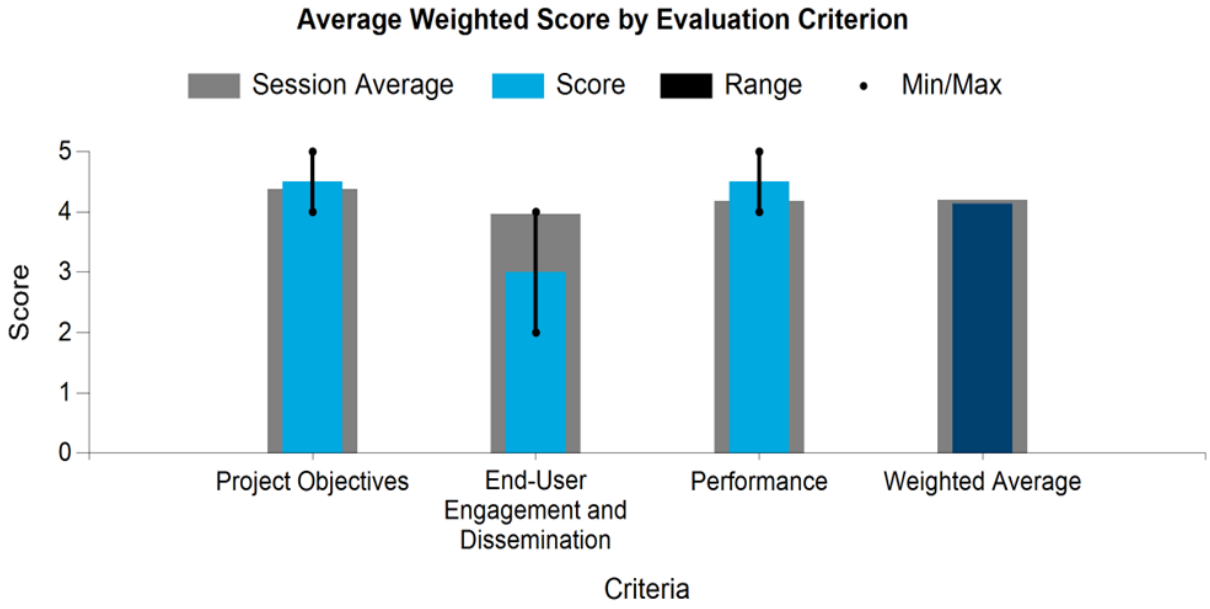
University of Alaska Fairbanks

WBS:	EE0008389
Presenter(s):	Jeremy Kasper
Project Start Date:	06/01/2019
Planned Project End Date:	01/31/2022

Project Description

The Water Horse is a vertical oscillator, hydrokinetic harvester designed by Renerge, Inc. to harvest energy from turbulent water conditions previously deemed unrecoverable. The technology focus is on small, remote, riverine applications where deployment with larger tidal turbines is challenging due to water depth laminations.

This CEC harnesses the gallop motion that results when a bluff body immersed in moving water induces alternating lift through vortex shedding and fluid-body interactions. Through a mechanical transmission linked to a permanent magnet generator, the Water Horse translates the resulting oscillations into electrical power. The system's unique design allows for placement of the generator and structural elements above the water line with the goal of keeping the overall system cost low. The bluff body is connected to the suspension system via a single arm, which allows for incorporation of a break-away mechanism to minimize damage from debris. During the project, a power electronics system consisting of a buck charge controller and battery energy storage system was developed to translate the pulsed electrical voltage from the generator into stable, usable electric voltage. Other design modifications include changes to bluff body size, oscillating frequency, and the PTO based on lessons learned from field testing in 2020. The updated prototype tested in 2021 incorporated uncoordinated upstream and downstream systems to investigate coupling effects between adjacent oscillators. Preliminary analysis indicates the water-to-wire efficiency of the overall system improved from 2.8% to 7.8% due to the design changes. The LCOE will be estimated before the conclusion of the project in late 2022.



Aggregated Reviewer Comments

- This project focuses on the WPTO objective to design and test modular, low-flow, river instream devices. The market for this device is currently limited to off-grid communities with very high energy prices currently. By admission, only very limited end-user engagement has occurred, although the team does have a level of understanding of end-user needs. The project has predominantly delivered on its objectives and multiple lessons have been learned that can feed into future development.
- The project objectives are compatible with the TRL and are covering relevant issues. Dissemination from the project is limited due to low TRL. Nevertheless, the team could make some contact with potential beneficiaries of the technology. This would also give valuable input for the development of the technology such as the development of user requirements. The performance seems to be in line with the objectives. There are many lessons coming from the project such that it will redirecting efforts and focusing on further systems such as debris protection.
- This is an interesting RoR project that is an excellent fit with the WPTO program. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment. The reviewer believed end-user engagement and their specific requirements could be very significantly improved. It appears there will be very significant challenges in bringing down the cost of the technology. Although there had been some minor supply chain issues, the project was completely on track.
- This is a great project. It is clear in objectives and had a manageable path to the goal. The results are impactful. Using the standards is important, and this stands as a test case of a kind. The approach, the data acquired, and the dissemination pathways are important for the wider industry. Validation of their numerical model is valuable for any research being done in this field. The results and the efficiency and design improvements were very successful. The lack of information provided on the end user is a weak point. It is not clear if there is a viable commercial pathway. The industry partner appears to be very quiet on this project and watching the university prepare results. It is important that they are contributing market study research and have a clear understanding of who is likely to purchase a system like this.

Performance Optimization and System Demonstration of a Multi-Mode Point Absorber

Oscilla Power, Inc.

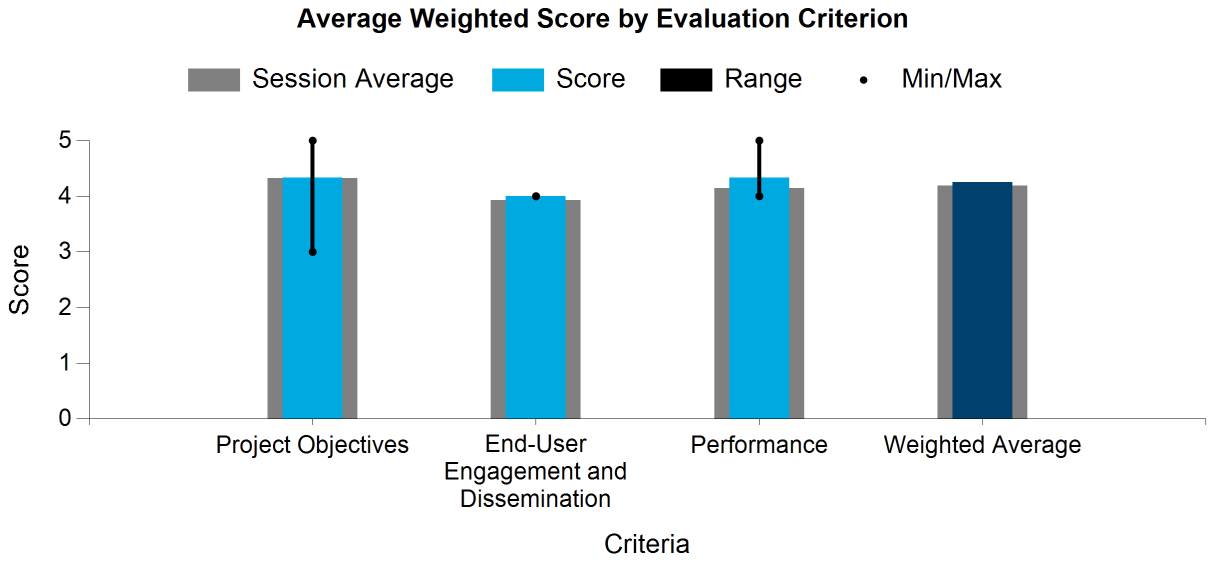
WBS:	EE0008625
Presenter(s):	Tim Mundon
Project Start Date:	06/01/2019
Planned Project End Date:	11/30/2021

Project Description

Oscilla Power is continuing to advance the design of the utility-scale Triton WEC through further optimization, followed by a demonstration at a reduced scale. Oscilla has identified multiple optimization pathways that are being explored in this work, such as geometric optimization, advanced controls and materials, improved installation approach, and others. So far, the project team has met or exceeded all performance goals outlined in this project for Triton, including power performance, capital and operating expenditures, and LCOE.

In budget period two of this project, the team will validate the identified optimizations through a 1:6-scale ocean deployment in a representative climate. This will be achieved during a three-month deployment at a location off Castine Island in Maine. This location has a suitably scaled environment that matches a U.S. West Coast wave climate. This deployment will allow the team to demonstrate the operation of the Triton and validate system operations and power performance, increasing the TRL from five to six.

A separate project (DE-EE0009954) will develop this concept into a complete, detailed design for a full-scale, 1 MW Triton unit for installation at PacWave. Demonstration of the Triton technology at a sufficiently large scale is required for serious engagement by established industry players, and this work forms an important milestone in this process.



Aggregated Reviewer Comments

- This project focuses on iteration of an existing design with key identified areas for improvement. There is a clear link to WPTO objectives by improving on the state of the art with the developer seeking to ultimately deliver a megawatt-scale system. There is a sensible and coherent project plan. End-user engagement has occurred and identified what needs to be delivered (a validated system) prior to significant further development. There has been successful project delivery to date, and a sensible onward plan has been communicated.

- There are clear objectives and they are compatible with the overall level of TRL. Dissemination work is directed toward stakeholders. Technology transfer to industry is limited. Performance seems to be performing clear steps to achieve the objectives. The deployment of 1:6-scale prototype will provide valid learnings.
- This is an interesting Oscilla Power project that is an excellent fit with the WPTO program and has tangible and useful outputs. Although the project appeared on track, the development plan was not fully clear. Additionally, there could be more attention to risks and their assessment. Although there was an end-user engagement strategy and targeting at the utility scale, the reviewer believed engagement with the user on their specific requirements could be improved. There had been no supply chain issues at this stage, and the project was on track.
- The project is well designed and well planned. The data captured to date is encouraging. The LCOE numbers seem optimistic. The reviewer expressed concerns about the robustness of the design. The submerge feature is interesting; however, it is not clear if this is enough for the sea states being proposed.

Cycloidal Wave Energy Converter

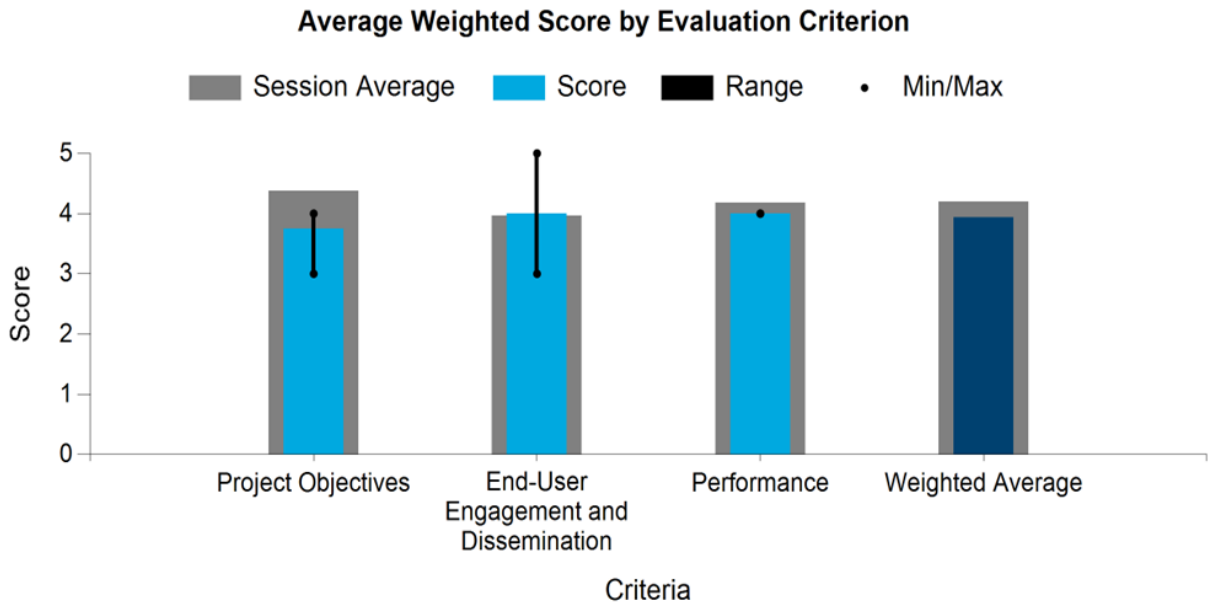
Atargis Energy Corporation

WBS:	EE0008626
Presenter(s):	Stefan Siegel
Project Start Date:	09/01/2019
Planned Project End Date:	09/30/2021

Project Description

The overall goal of the proposed project is to advance the design maturity of the Atargis proprietary Cycloidal WEC from TRL 4/technology performance level (TPL) 7 at the beginning of the project to TRL 6/TPL 7 at the end of the project. This will be achieved by means of numerical simulations at the model scale as well as 1:15-scale wave tank tests. The comprehensive test plan for both will cover all conditions encountered by the device throughout its service life from commissioning to decommissioning. With the expected outcome of the experimental results matching the simulations performed at full scale prior to the start of the proposed work, the Cycloidal WEC will have advanced to TRL 6 and maintained a TPL 7 or higher and will thus be ready for future open ocean tests.

During budget period one, three main technical activities took place: design of a 1:15-scale wave tank model, numerical simulations at the model scale, and bench testing of key model components. The efforts during budget period two will be primarily focused on model construction, commissioning, and testing. Testing will cover harmonic wave generation and cancellation, irregular wave cancellation, short crested waves, storm survival, maintenance, WEC commissioning, and decommissioning. The three-month testing campaign will be the highlight and central activity of the entire program.



Aggregated Reviewer Comments

- The end goal for this WEC is megawatt-scale wave energy and, therefore, in keeping with WPTO objectives. There is a sensible plan concentrating on initial small-scale prototypes and testing, development, and validation. A sensible project plan was proposed and is being delivered. The team has clearly looked at and thought about installation and survival operations and developed systems accordingly. The risk analysis is noted as having been done as part of the project, but it was also noted that the main approach to managing risk is use of tried-and-tested technology. Technology transfer from other industries is being used, which

is good, but the reviewer has a residual concern that there is a level of overconfidence in the reliability of such technology straight away in a wave energy application despite wave energy being a novel environment for the technology (with associated high-risk levels until qualification is complete). Dissemination of results has occurred, but there has been limited end-user engagement at this stage. An intended basic plan to commercialization was not presented.

- The project objectives are in line with the TRL and WPTO objectives. Dissemination seems far from commercialization, and this is probably due to the present stage of development.
- This is an interesting wave project that is an excellent fit with the WPTO program with tangible and useful outputs. The ability to scale is a major attraction of the technology. Although the project is using the lab's LCOE model, the reviewer believes there needs to some validation of the inputs to the LCOE model. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment. Although there was an end-user engagement strategy, the reviewer believed this engagement with the user and their specific requirements could be improved. It was difficult to assess the overall progress and performance of the project as it is now on hold for cost-share fundraising.
- This is a very interesting design. Comprehensive work was done to get the results presented. The reviewer would encourage the team to engage an industry partner to see if this design is something that would have commercial potential.

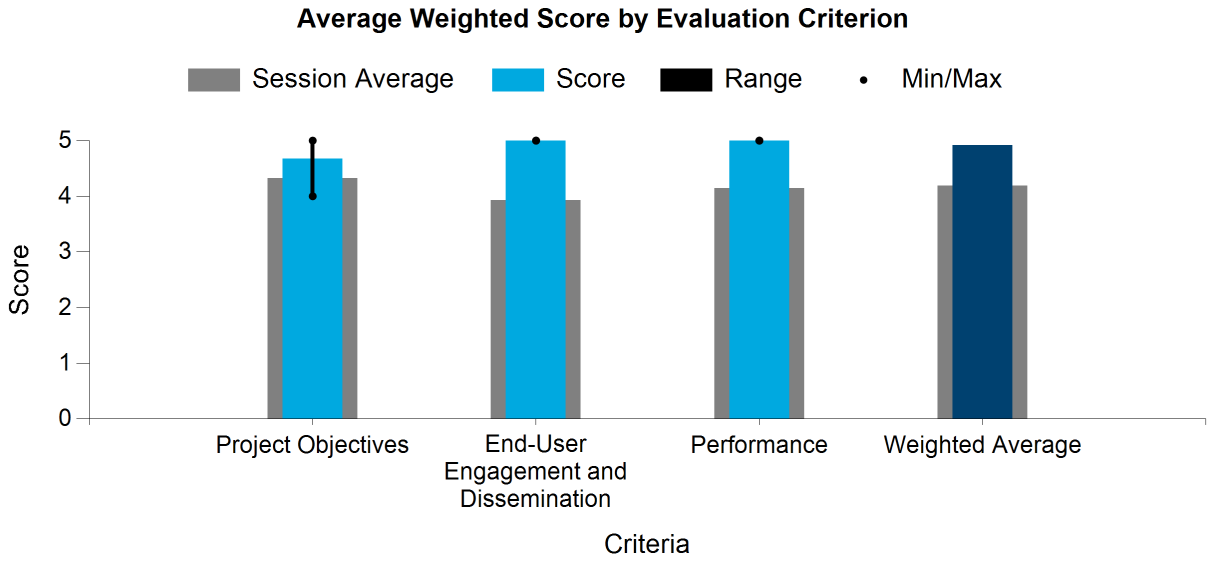
Design, Build, and Test of Novel, Remote, Low-Power Wave Energy Converter for Non-Grid Applications

C-Power

WBS:	EE0008627
Presenter(s):	Erik Hammagren
Project Start Date:	05/01/2019
Planned Project End Date:	09/30/2022

Project Description

The proposed project goal is to design, deliver, and test a novel, low-power autonomous offshore power system that lowers operational costs, complexity, and carbon intensity and provides robust, new capabilities for customers in the maritime environment. The autonomous offshore power system is a WEC-based system that builds on C-Power's prior R&D efforts and is intended to be an easy-to-transport, reliable, and survivable power and data communications system for resident mobile and static marine assets, such as data-gathering systems and uncrewed vehicles, for applications in shallow- and deep-water locations that lack desirable, resident, and/or sufficient power sources. The prototype WEC, the SeaRAY, is designed with the ability to be rapidly deployed, has power electronics with integrated energy storage, and can deliver continuous power to supported assets as required. The project will demonstrate the SeaRAY autonomous offshore power system's high techno-economic appeal for the marketplace, appropriately balancing survivability, cost, and ease of handling/servicing with a clear path for future open-water testing at a larger scale and in deeper water. Once designed and built, the full system will be deployed for six months at WETS where it will demonstrate the ability to generate and store electricity for powering the various seafloor assets connected to it as well as to provide the assets with a connection to the data cloud.



Aggregated Reviewer Comments

- This project focuses on powering the blue economy, which aligns well with WPTO stated objectives. Learnings from this project will also feed into other projects by the same developer with a focus on larger-scale WECs. Technology developed as part of this project (such as the electro-optical-mechanical mooring line) has applicability to other projects and industries. A sensible project plan is being delivered, and the reviewer especially liked the apparent robust design approach that includes significant lab validation of components and subsystems prior to integration with the wider system and at-sea deployment. Clear end-user engagement has occurred.

- Objectives are in line with the requirements of the program. Considering all the fast development and deployment of autonomous vehicles, it is an interesting application. It seems that the early work done has supported efforts to define the functionality (engagement with potential customers and deployment of a small-scale prototype, for example). Dissemination and engagement with potential customers seem very positive, and the reviewer believes that needs to continue as the requirements will be changing quickly as the autonomous vehicles are evolving fast. Regrading performance, it seems to be progressing in line with the objectives.
- This is an interesting project that is an excellent fit with the WPTO program with tangible and useful outputs. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment. Although there was an end-user engagement strategy, the actual engagement with the user and their specific requirements was also good. Although there had been some supply chain issues out with their control, the project progress and performance were on track.
- The focus on low cost and ability to deploy is positive. Engaging early with customers is encouraging. The design experience on previous iterations has clearly allowed the company to build a system that can reach higher TRLs quickly.

XCT System for Harvesting In-Current Hydrokinetic Energy from Low-Velocity Sites

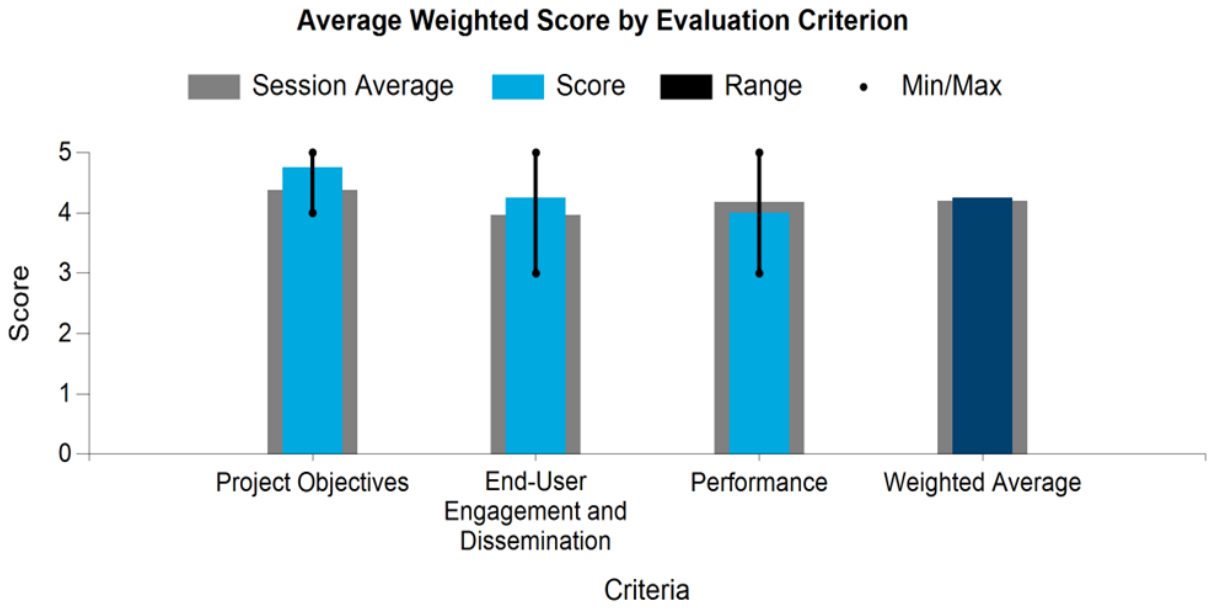
Littoral Power Systems Inc.

WBS:	EE0008628
Presenter(s):	David Duquette
Project Start Date:	08/01/2019
Planned Project End Date:	12/31/2022

Project Description

The kinetic energy in river and ocean currents is an abundant resource that could support a potential $20 billion global market. However, an estimated 80% or more of this potential is in relatively slow-moving waters where currents flow at 2 meters per second or less. Unlocking this resource with an economically viable technology is a challenge since these slow speeds characterize nearly all in-current hydrokinetic energy resources in the United States. While pioneering teams have installed CEC projects, there are still no viable technologies to harness this resource that even come close to generating electricity at utility-scale pricing.

In early 2017, Littoral Power Systems began to conjecture that moving small, inexpensive turbines through the water rapidly could give rise to much lower LCOE than conventional devices. With a lift device in an open fluid, power harvest grows as a cubic function of velocity but only as a linear function of swept area, and it stands to reason that swept area could be traded for velocity. Littoral Power Systems subsequently developed a concept for a crosscutting turbine known as the XCT. The XCT machine is simple and reliable and eliminates gearboxes. It is anticipated to reduce maintenance requirements and can be used with a variety of inexpensive mooring and deployment strategies. The purpose of the work is to understand performance characteristics, identify and mitigate reliability risks, and provide data to advance the CEC industry toward achieving cost competitiveness in sites that were not previously practical economically.



Aggregated Reviewer Comments

- This is an interesting concept the reviewer had seen before. A sound rationale for development was put forward, and a sensible project plan was developed and is being delivered. This project is well aligned to WPTO objectives. The reviewer especially liked the approach statement that "the ocean always wins" and the design

philosophy that was developed accordingly. The reviewer sees potential for technology transfer for flooded components. Failure mode effect analysis was mentioned, and the project changed in response to this, giving confidence to a robust overall approach to technology development. End-user engagement was conducted. Dissemination was conducted and a base of a commercialization plan was mentioned. The team is addressing project challenges with respect to IEC standard compliance positively, but the reviewer suggests that, if possible, discussions with the standards developers may be beneficial to see what the intent of the specific clause is and if or how that applies to the CEC being developed where multiple rotational axes exist. Learnings are being gained and incorporated into the future project plans. Collaboration with other funded projects is apparent.

- The objectives are in line with WPTO objectives. Engagement with potential users has been carried out. The presenter referenced Minesto, which is positive as they are looking for experiences from systems with a similar approach. Regarding performance, the project has progressed, although late due to supply chain issues. It was stated that failure mode effect analysis has been extensively used. The reviewer recommended adapting the requirements from the IEC TS 62600-200/300 to the technology.
- This is an interesting project that is an excellent fit with the WPTO program, although there is a lack of clarity on how meaningful the results will be. They have a well-developed and thought-through plan and a good risk register. The reviewer believed their end-user engagement strategy and engagement with the user and their specific requirements could be improved, and there was no clear appreciation of market size and requirements. They do expect some supply chain issues in the future, which are out with their control, and the actual progress and performance of the project is on track.
- Plots or charts of the results would be valuable to see. A cut in speed of 0.35 m is interesting. Seeing the power curve would be very helpful for understanding the potential for this system. The design approach is sound. The customer interviews approach is very encouraging. The economic approach is critical to have success in this sector.

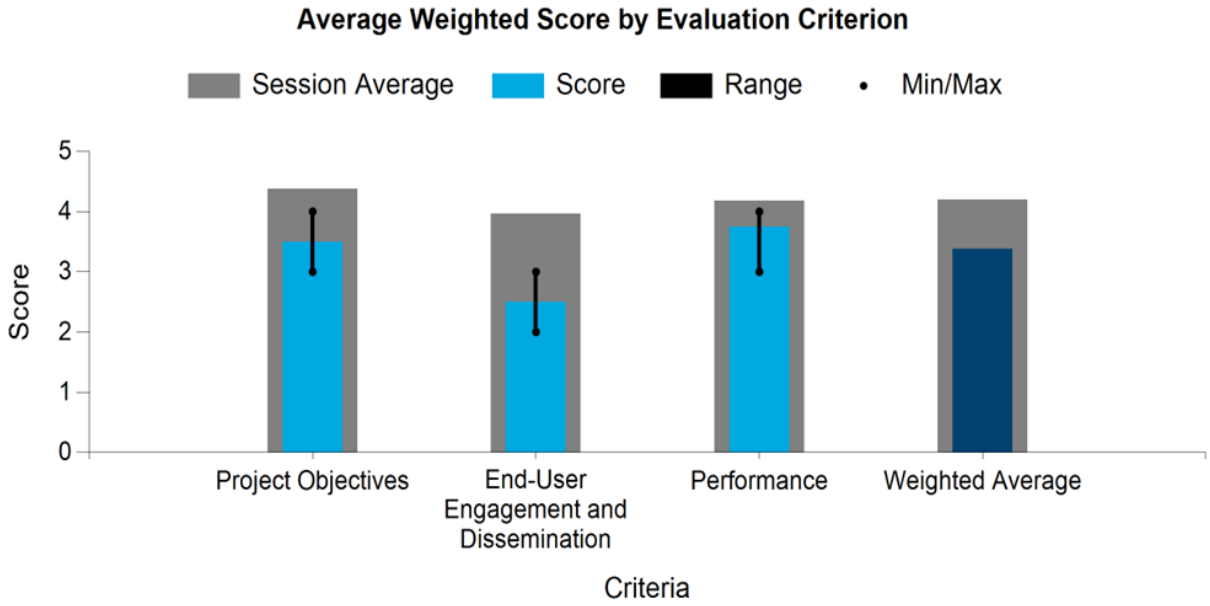
Hawaii Wave Surge Energy Converter (HAWSEC)

University of Hawaii Systems

WBS:	EE0008629
Presenter(s):	Patrick Cross
Project Start Date:	09/01/2019
Planned Project End Date:	09/30/2022

Project Description

This project aimed to develop an oscillating wave surge energy converter concept through numerical modeling and wave tank testing at two scales: 1/9th and 1/3rd. The project utilized off-the-shelf or readily fabricated, proven hydro turbine concepts for power takeoff, which represented an opportunity for LCOE reduction. The project team investigated both high head and high flow versions in budget period one (small scale) before down-selecting in budget period two (medium scale).



Aggregated Reviewer Comments

- The project's initial focus is on PBE applications, which links well to WPTO objectives. The team also has a stated ambition to scale up, but the plan for doing this is not clear at this stage. The team does not appear to have sought to engage with previous flap-type WEC developers or expertise to leverage their experience and expertise. This may help shape more efficient project programs with greater value being delivered overall from leveraging that previous experience. Challenges experienced have been dealt with by the project team to keep the project moving forward. The focus for LCOE improvement is on utilization of commercial, off-the-shelf equipment. The concern, as for other projects, is that there is an overconfidence on this equipment's reliability in a WEC context with WEC-specific loading requirements, etc. Technology qualification is a must, and risks must be managed accordingly throughout the process. Limited user engagement has occurred to date, but the project team recognizes that this needs to increase.
- Objectives are in line with the TRL. It is interesting that some initial indications are obtained regarding degradation of the different systems. Regarding engagement, maybe engagement with stakeholders is a bit early, but nevertheless, some identification of user requirements would be useful. Regarding performance, it was unclear to the reviewer how lessons from previous surge devices were taken on board. The selection of the size of the device may help to overcome the issues faced by Aquamarine. (That was a large-scale, megawatt device.)

- This is an interesting surge wave project that is an excellent fit with the WPTO program and has tangible and useful outputs. The overall development plan is not clear, and there could be more attention to risks and their assessment. It is not clear who the end user of this technology will be, and there appears to have been little or no end-user customer engagement. The overall project has made good progress so far. International engagement with similar technologies would help transfer lessons learned and avoid duplication of effort in this project.
- The work was well executed. The design is robust and has a simplicity that is attractive. The team has not engaged with any potential end users. Even if this is at an early stage, a customer needs to be identified if the project is not simply an academic exercise. It appears as though this will be directed to island and remote communities. There should be a stakeholder engagement plan early in the design stage to ensure that there will be some future for this design.

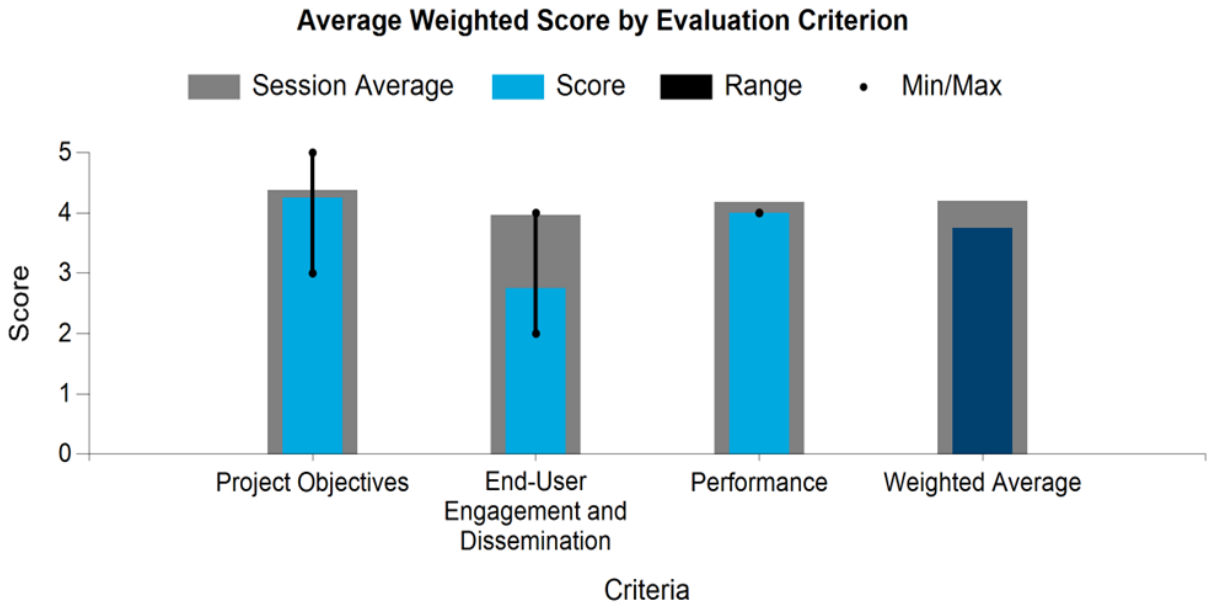
An Innovative SR-WEC for a Market-Disruptive LCOE

Texas A&M Engineering Experiment Station

WBS:	EE0008630
Presenter(s):	HeonYong Kang
Project Start Date:	09/01/2019
Planned Project End Date:	01/31/2023

Project Description

This project aims to develop and test a scaled prototype of the Surface Riding Wave Energy Converter (SR-WEC), which can produce average power in the scale of 5 kW for a market-disruptive LCOE below 40 cents per kilowatt-hour by combining an extended operating window; amplified average power output by simple but optimum control, adaptable to varying sea states in peak periods; and costs consequently lowered by the high performance over the wide range of sea states. While developing the design methodology and proper simulation tools with correlation to experimental data, the project intends to complete optimum design of SR-WEC for the maritime market applications; confirm full performance of the 5 kW SR-WEC using scalable wave tests of the scaled prototype in the ocean basin and advanced, fully nonlinear global performance simulation; confirm the market disruptive LCOE for single operation in the target application using the global performance simulation correlated with the scalable tests; and identify remaining uncertainties and risks to be resolved in the larger-scale prototype tests.



Aggregated Reviewer Comments

- This project appears to be more focused on foundational R&D rather than technology validation (e.g., outputs include tools for the wider WEC community), but it is attempting to address stated WPTO objectives. The project description includes ensuring extended operating windows and lower costs, but this is not mentioned again in the presentation. It is unclear if these objectives have been delivered or are being considered. The project appears to be focused on the WEC rather than wider wave energy infrastructure and costs required. Sound research is being conducted and information and understanding are being developed, but it is not clear that all stated project aspects were considered as yet. End-user engagement was not conducted, but some dissemination of information is occurring. There is no clear path to commercializing at this stage.

- Considering the low TRL, the objectives are in line with the requirements of the program. Regarding dissemination, the reviewer was not sure on the end-users list, but it is a good initiative to look at the market for a 5 kW device. Regarding performance, it is in line with the objectives and low TRL, early-stage technology. It would be useful to declare the level of uncertainties in the LCOE evaluation and follow up on the next steps as more information is obtained. If a large device is to be considered, careful consideration should be given to the challenges of scaling up, achieving competitive LCOE, and the reliability and feasibility of the components.
- This is an interesting project that is an excellent fit with the WPTO program with a robust project plan. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment. To date, there had been no end-user engagement, but this was planned for the future. There has been good progress with a good research methodology.
- There are many potential uses for this system, and it is being well designed and tested. It is not clear what performance results are real and which are estimates and anticipated. The presentation of the work would benefit from some more traditional power curves. It is likely most of the work is getting the system working, but there should be some measurement of power at all stages of development. Additional detail on the expected LCOE would also be valuable. The reviewer inquired about the opportunities for LCOE reduction, the costs, and how economy of scale influences this. There is a plan to engage end users, but it is not clear if any have been approached. This needs to happen sooner than later. There will be a lot of time and effort in this system, and if there are fundamental challenges with the design for user applications, this should be identified now.

Device Design and Robust Periodic Motion Control of an Ocean Kite System for Hydrokinetic Energy Harvesting

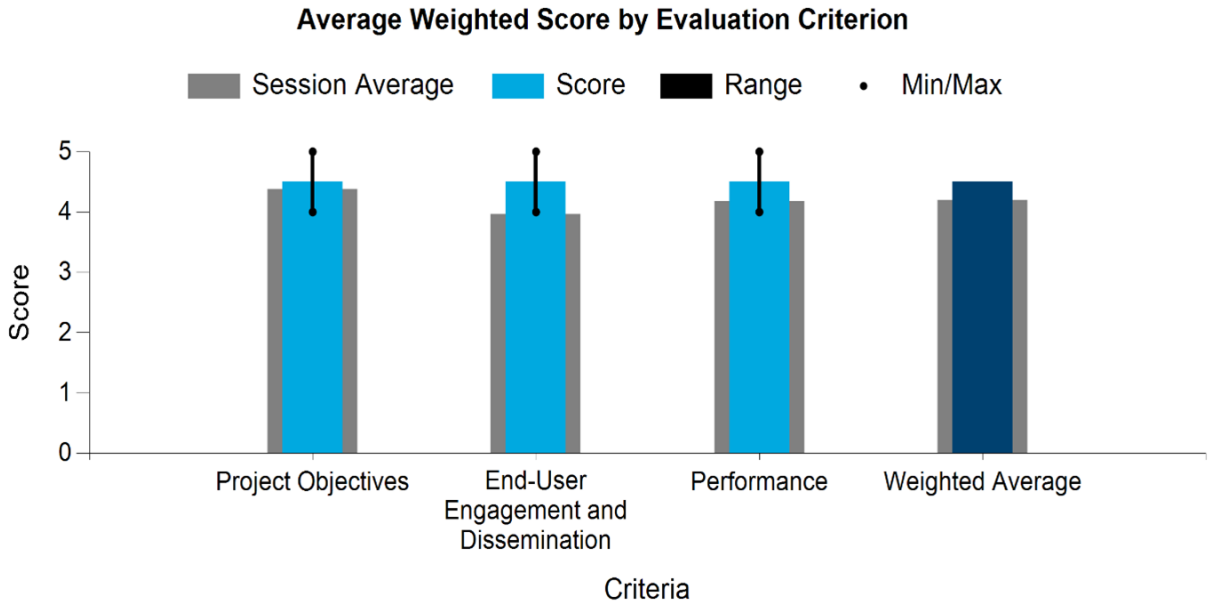
North Carolina State University

WBS:	EE0008635
Presenter(s):	Chris Vermillion
Project Start Date:	05/01/2019
Planned Project End Date:	04/30/2022

Project Description

This project aims to develop a unique design, open-source modeling tools, and periodic optimal control systems for a unique variant of an energy-harvesting underwater kite. The technology will rely on a winch system for power generation, spooling tether-out under high tension in high-speed, cross-current motions and spooling-in under low tension. This removes all rotating machinery on the kite but demands an efficient design, spooling algorithm, and an algorithm for setting/adapting the kite's flight path. These algorithms are instrumental to the system realizing its full techno-economic potential. Technology-to-market development efforts primarily focus on identifying early adopters of the technology at relatively small scales, focusing attention on blue economy applications such as autonomous underwater vehicles and observational station charging.

The team has developed a suite of open-source dynamic modeling tools that characterize the kite, tether, environment, and floating platform (if the kite is deployed off a floating platform). The team has adapted economic iterative learning strategies to the challenges of cyclically optimizing spooling and flight profiles, developed a three-level progressive experimental prototyping framework for validating its models and controllers, and validated its models and control approaches in all three environments. Additionally, it has secured ongoing funding from a top defense contractor to further develop the kite technology to provide power to long-endurance, high-payload autonomous underwater vehicles.



Aggregated Reviewer Comments

- This early-stage project is looking at the fundamentals of the technology, so the technology is a bit further into the future, but the team has identified follow-on projects that would be required to take further steps toward commercialization. The open-source nature of outputs has potential for value in more projects than just this one. There is a sound project plan that steps up through progressively more challenging tests. The reviewer

really liked the iterative learning that was incorporated and can see this experience being of benefit to more projects. It is good that collaboration with Minesto is being sought and discussions are underway. The reviewer applauds the team for reaching out to industry to leverage learning and increase the value of the project to industry accordingly. End-user engagement has occurred as evidenced by work with Martin Defense Group, but wider engagement with other potential end users would also be beneficial to ensure widest possible applicability.

- This project has a good dissemination and engagement program. Open-source controls provide a good input to industry. It is a good approach to contact Minesto, but it would probably be useful to contact kite developers for wind. An adaptation of IEC TS 62600-200 requirements is required. Regarding performance, the plan and results so far are in line with the project objectives.
- This is an interesting tidal kite project that is an excellent fit with the WPTO program, although there is a lack of clarity on how meaningful the results will be. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment as this is potentially a high-risk, high-reward project. Although there is good contact with Martin Defense, the reviewer believed the project's end-user engagement strategy and engagement with the user and their specific requirements could be improved. There has been good actual progress and a future plan. There is good engagement with their European counterpart, which is essential to avoid duplication of effort.
- The project has made excellent progress. Great presentation of powering data, and the end-user engagement is very positive.

Low-Flow Marine Hydrokinetic Turbine for Small, Autonomous, Unmanned Mobile Recharge Stations

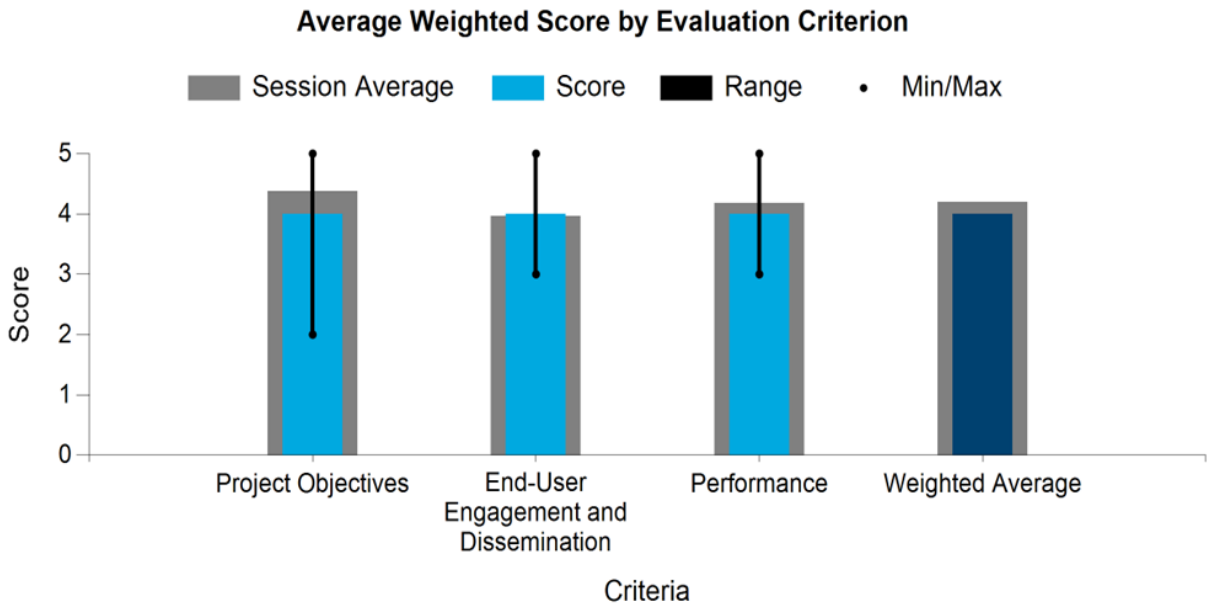
Florida Atlantic University

WBS:	EE0008636
Presenter(s):	Manhar Dhanak
Project Start Date:	07/01/2019
Planned Project End Date:	06/30/2022

Project Description

The project goal is to develop a prototype low-flow (0.5 to 1.0 meter per second) marine current turbine to provide partial power to recharge battery banks onboard an unmanned mobile floating recharge station for small aerial drones. A small autonomous surface vehicle available at Florida Atlantic University serves as the mobile floating platform from which the turbine is to be deployed. Sub-components of the system being developed include an undershot waterwheel, a PTO device, an automated platform anchoring system, and a flight-deck onboard the platform to support landing, takeoff, and charging of small aerial drones.

Specific objectives are to design and develop a prototype undershot waterwheel and other subsystems utilizing commercial, off-the-shelf components wherever possible; conduct laboratory tests and, once environmental permits are granted, field tests that will be conducted in the tidal flow-driven intracoastal waterways and coastal waters offshore of Ft. Lauderdale, Florida; analyze acquired data for assessment of system performance; and develop plans for market transformation and engage industry.



Aggregated Reviewer Comments

- The reviewer's perception is that this is a niche market being targeted with limited wider applications. The reviewer would have liked to see more about the application use cases and potential end users plus any limitations or specific requirements of the industry (such as sea states for use or seabed conditions required) to confirm commercial onward viability of the system. (The reviewer notes that some potential users have expressed an interest in the project.) End-user engagement is occurring but would benefit from being better integrated into the project to ensure end-user requirements are being met. The approach to use an already available unmanned vehicle is reasonable but learning with respect to the CEC will be limited based on design

choices made. The benefit of the project will therefore be focused on integration of systems and addressing those challenges.

- Regarding objectives, it is important to check that the efficiency and strength of the PTO is satisfactory in actual sea conditions as it seems to be able to attract a considerable loading. It is understood that the sea conditions will be compatible with drone operation conditions. However, swell waves can be disconnected from wind conditions. The reviewer inquired whether it would be in the plans to provide multiple drones charging at the same time. There is a good engagement plan. Regarding performance, the project is focused on the initial objectives.
- This is an interesting tidal stream project that is an excellent fit with the WPTO program, although there is a lack of clarity on how meaningful the results will be. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment. Although they say they have end-user interest, the reviewer believed their end-user engagement strategy and engagement with the user and their specific requirements could be improved. There have been good bench tests and good overall progress.
- This is a great project. The direct planned application is ambitious, but the unmanned autonomous vehicle is not the challenge for this project. The partners engaged and planned for engagement are a great choice for this project. The performance data is well presented and shows a viable system. Additional information on the storage system, if there is one, or the ways of dissipating energy when not in use would be interesting.

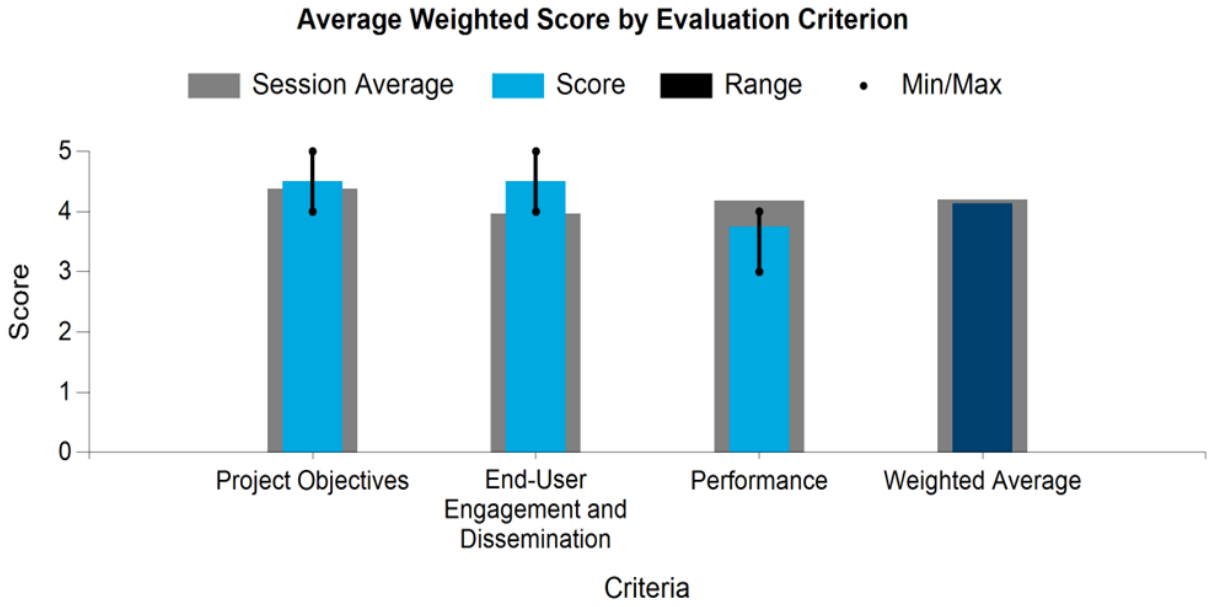
Modular RivGen

ORPC

WBS:	EE0008948
Presenter(s):	Ryan Tyler
Project Start Date:	03/16/2020
Planned Project End Date:	05/15/2023

Project Description

The Modular RivGen development project aims to create a hydrokinetic power system that can be rapidly installed, produce meaningful power in low flows, and be easily scaled for array operations. When installed as an array, this system will provide a low-cost option for a wider market by identifying and targeting specific early adoption use cases. System designs were developed through market-based requirements, lessons learned over numerous past installations, manufacturing-based cost reduction strategies, and industry standards. Numerical and analytical models developed throughout this project have led to novel device structures and performance predictions, which exceed project goals. Partnerships with national laboratories will provide independent validation of performance predictions and further insight into market resources. Full-scale deployment of a two-unit connected array will validate system costs, operations, and performance, providing a critical step toward commercialization of the technology. Through its development and validation, the Modular RivGen will address a fundamental challenge of the hydrokinetic industry of how to reduce cost of electricity while operating in less energetic environments.



Aggregated Reviewer Comments

- This project adapts current technology to make it more adaptable to different use cases and deployment environments to enable near-term deployment of river generation systems, which is well aligned to WPTO goals. It also builds on previous experience and projects and extends and iterates from them. There is a robust system development plan that includes both laboratory and field testing to mitigate risks during the development process. The project also included third-party review, which is good to hear. End-user engagement has occurred and continues.

- Regarding objectives, although modularity is expected to help on installation of arrays, it would be interesting to include consideration of maintenance (such as repair on one module or replacement of any module). It would also be useful to consider debris management. Regarding dissemination and engagement, there seems to be a good plan. There is also a study on how to adapt IEC 62600-300 to the technology. Regarding performance, the actions to achieve the project outcome seems adequate considering the proposed objectives.
- This is an interesting project that is an excellent fit with the WPTO program. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment. It was believed their end-user engagement strategy and engagement with the user and their specific requirements could be improved, including the target size of the product required. There is a good methodology and progress, although they expect some supply chain issues in the future.
- A modular system is a great design for lower flows, and the potential for commercial success is high. The performance data is not present in a way that allows full understanding of the capabilities of the system. Claims are made with no data or metrics presented to back them up. The interviews are encouraging. It is not clear what dissemination of this work has been done to date.

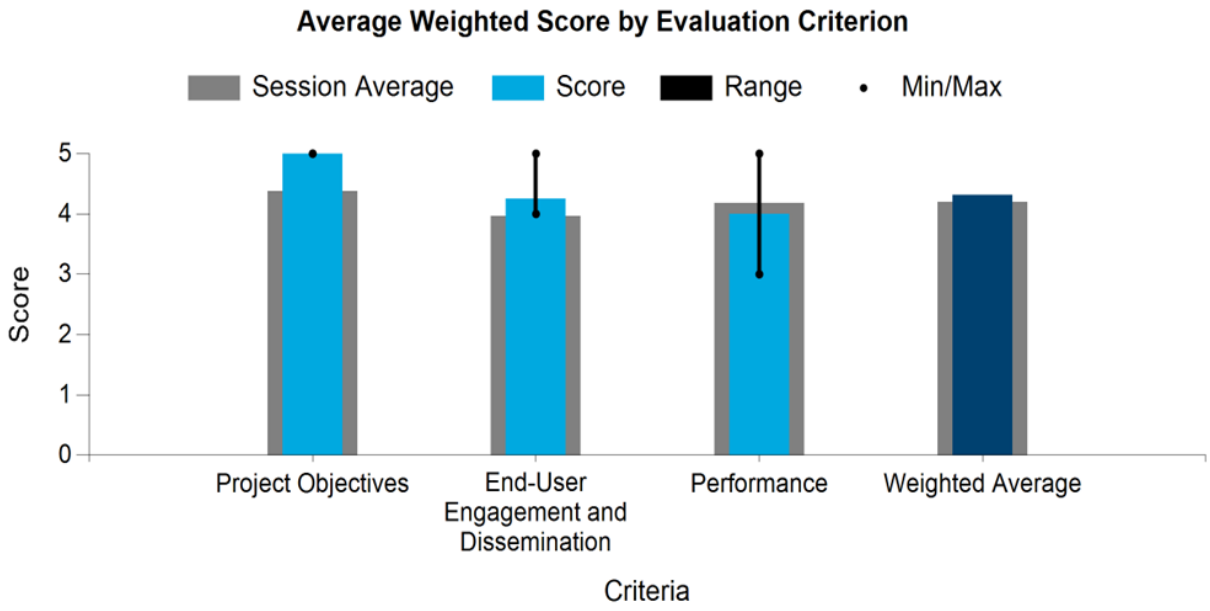
Advancing CalWave's WEC Design for PacWave

CalWave Power Technologies Inc.

WBS:	EE0008951
Presenter(s):	Thomas Boerner
Project Start Date:	03/01/2020
Planned Project End Date:	09/30/2022

Project Description

The objective of this project is to evolve the xWave detailed design to a scale for island/remote markets and ensure the device design is suitable for deploying at the PacWave South test site. A smaller-scale xWave system was developed with DOE support under FOA-1663 and has completed 10 months of open ocean testing in San Diego. This project scales up the xWave architecture to a size relevant for remote and island communities.



Aggregated Reviewer Comments

- This project builds on previous projects and is focused on PacWave deployment in the near future, which is clearly aligned with WPTO objectives. Comments such as "path toward certification," "risk evaluation and mitigation," and "criticality of pre-deployment testing" give confidence to the approach being taken. These statements were supported through questioning after the presentation. The company is engaging with end users and seeking avenues toward commercialization, including looking at co-location with wind.
- Objectives are in line with the requirements from the program. Engagement and dissemination are satisfactory to the objectives, and it seems to be a good platform for the long-term definition of the market and users' requirements. Performance activities are well defined and in line with the objectives of the project. It was unclear to the reviewer how the power cable is designed considering an additional aspect of changeable submergence of the floater.
- This is an interesting wave project that is an excellent fit with the WPTO program. They have a well-developed and thought-through plan, but there could be more attention to risks and their assessment. It was believed their end-user engagement strategy and engagement with the user and their specific requirements could be improved. There is good overall progress and performance of the project.

- This is an exciting project. In the presentation, some names of potential customers or some blanked out statements of support would be helpful. Some charts or data showing the metrics of the work done in the project would be helpful in evaluation. It is not clear what is previous work and what level of detail has been accomplished in this project. The awards and event participation are very positive.

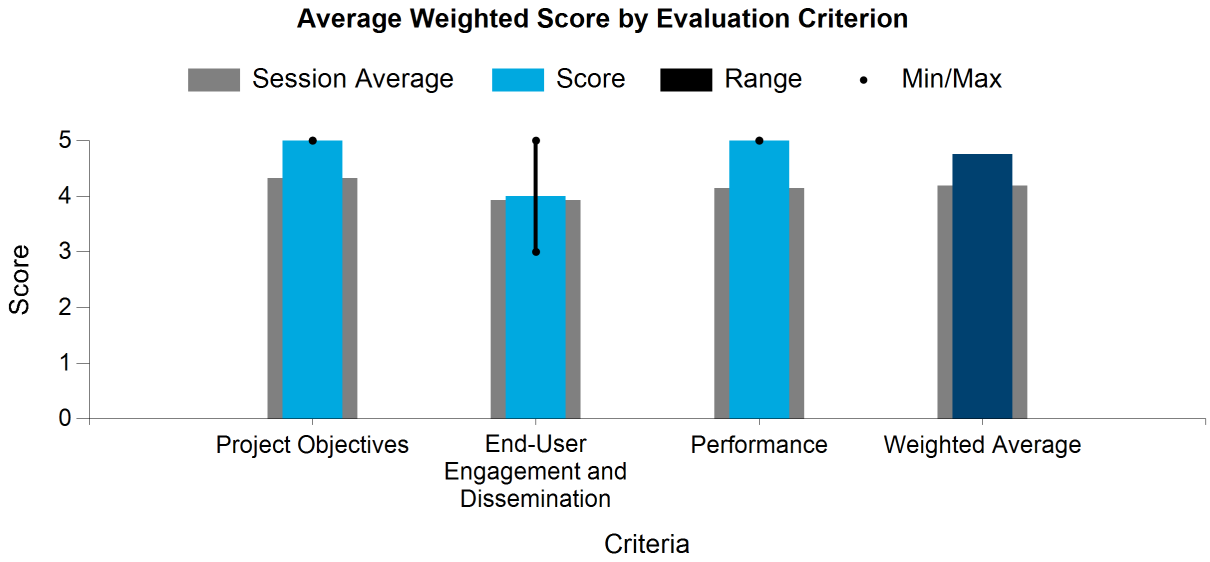
MARMOK-Oscillating Water Column (OWC)

Idom, Inc.

WBS:	EE0008952
Presenter(s):	Borja de Miguel Para
Project Start Date:	05/01/2020
Planned Project End Date:	04/30/2022

Project Description

The aim of this project is to advance the future commercial viability of the floating oscillating water column technology through the development of a commercial-size WEC specifically suited to PacWave South site conditions. This spar-type WEC design is based on a previous low-power prototype deployed and tested offshore for more than two years and incorporates several innovations to contribute to the LCOE reduction potential of the technology. It is a grid-connected prototype in which applicable IEC and IEEE standards have been followed. A technology commercialization plan has also been developed that identifies potential markets for each of the development stages.



Aggregated Reviewer Comments

- This is an impressive presentation and discussion. The project leverages and builds on previous experience with a view toward MW-scale WECs and the potential for near-term deployment and further learning. All major aspects of the full project were considered including WEC, O&M, moorings, umbilical, control, etc., and onward commercialization plan. There is a robust design approach that includes lab testing of critical systems within this pre-project, prior to ocean deployment of the full system. The project successfully delivered. Dissemination is occurring, and a commercialization plan was developed.
- The objectives are in line with the needs of the project (considering the previous work carried out in the technology) and in line with the program. The reviewer inquired about work involving export cable (installation and operation), plans for dry-testing of the PTO (including the turbine), and activities for definition of inspection and maintenance (including structure). Regarding performance, the project seems to be missing end users in the engagement. It is expected that the deployment of the previous prototype has given important input to LCOE evaluation.

- This is an interesting spar buoy project that is an excellent fit with the WPTO program. They have a well-developed and thought-through plan. There is an excellent engagement strategy and engagement with the user and their requirements. There has been good progress, and the team completed the overall project very well.
- This is a well-tested system. The use of standards is very positive. The results to date are very encouraging. It is not clear, however, if there has been much engagement with potential customers and end users. Use cases are identified, but it is not clear if these have been made in collaboration with stakeholders.

Floating Oscillating Surge Wave Energy Converter Using Controllable, Efficient Power Take-Off System

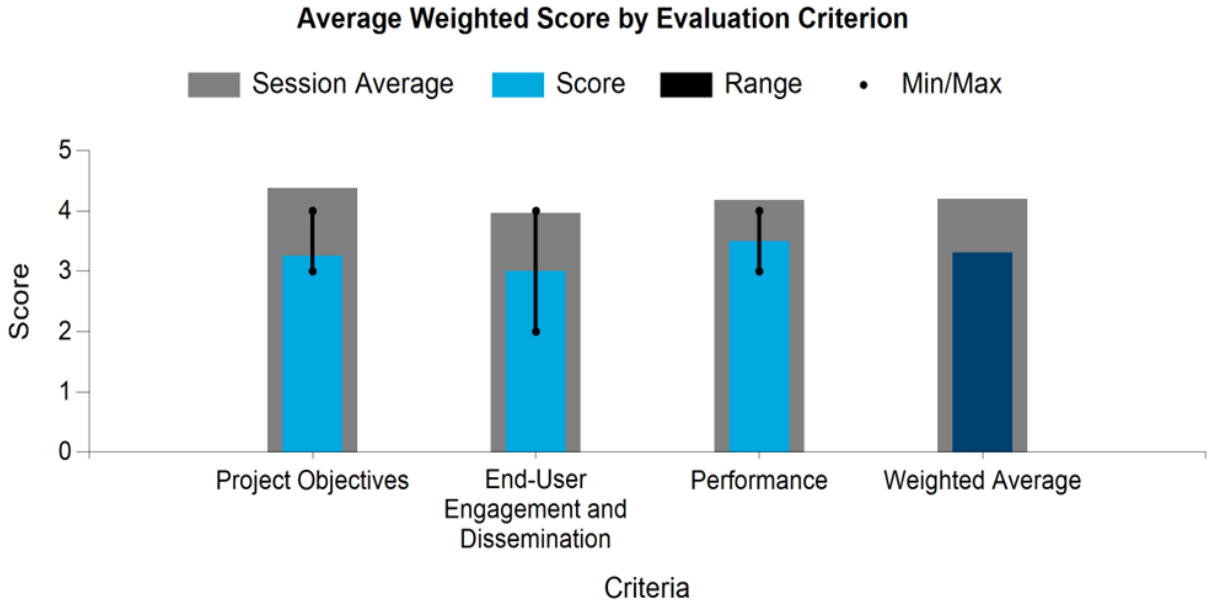
Stevens Institute of Technology (Inc.)

WBS:	EE0008953
Presenter(s):	Muhammad Hajj
Project Start Date:	06/01/2020
Planned Project End Date:	05/31/2022

Project Description

This effort is in direct support of expanding and diversifying the nation's renewable energy portfolio and is a critical step on the way to developing both grid-scale and distributed wave power generation systems by extending bottom-hinged surge wave converters in shallow water to converters placed over a floating platform. The innovative 100 kW, dual-flap floating oscillating surge wave energy converter (FOSWEC), as designed here, can be deployed at any water depth.

One innovation is to enhance the structural stability at minimum cost by placing the two flaps at an optimal separation. A second innovation is to design, build, and test an active mechanical motion rectifier as an integral component of the PTO system of the FOSWEC. The scope also includes development of a manufacturing plan, ocean test plan, risk register, compliance with IEC/IEEE standards, commercialization plan, and National Environmental Policy Act compliance requirements. Benefits of this design include increasing the capture-width ratio from 18% to 40%, reducing the peak-to-average ratio by 50%, and ultimately reducing the LCOE by 40% when compared to Reference Model 5. The ultimate goal is to build and test the designed system at the PacWave South test site.



Aggregated Reviewer Comments

- The floating flap-type WEC device is a different approach to flap-type devices than those previously seen (to the best of the reviewer's knowledge). Investigating this potential is therefore a reasonable thing to do in pursuit of marine energy advancement and is in line with WPTO objectives. The technology is at a relatively early R&D stage and requires significant development before at-sea testing can be realistic (e.g., as identified, further irregular wave or spread wave considerations and how these may affect technology). The team should be commended for seeking out expertise of Matt Foley with previous experience of a similar technology at a large

scale with at-sea deployment experience, but it was unclear to the reviewer how this guided the project's goals or objectives and if this had a very specific remit or was able to guide some of the technology more generally. Other previous technology development programs may also be of relevance as well as wider experience-based advisory to ensure that previous lessons learned are integrated from the outset. There are multiple areas of crossover from other technology development projects that could potentially be leveraged. Dissemination has occurred. It is also good to see engagement with third parties for verification purposes.

- The reviewer inquired as to whether there are any lessons learned from Langlee WEC (floating dual flap) established in 2006. The engagement of a third-party is positive. The scope hopefully addressed the whole technology. Dissemination and engagement do not seem to address end users and other stakeholders directly. Performance seems to be compatible with the stage of technology development.
- This is an interesting surge wave project, but it is not clear how meaningful the results will be compared to past surge wave projects. There could be significantly more attention to risks and their assessment. It was believed their end-user engagement strategy and engagement with the user and their specific requirements could be significantly improved. There appeared to be good progress and methodology.
- This idea has many risks and challenges. It is important that they are well described. Bringing in the ABS partner earlier in the design process would be beneficial as part of the project's next phase. It is not clear if there is an investigation or conversation regarding the commercial application of this system.

Optimization, Design, and Commercialization Planning of Next-Generation StingRAY H3 Wave Energy Converter

C-Power

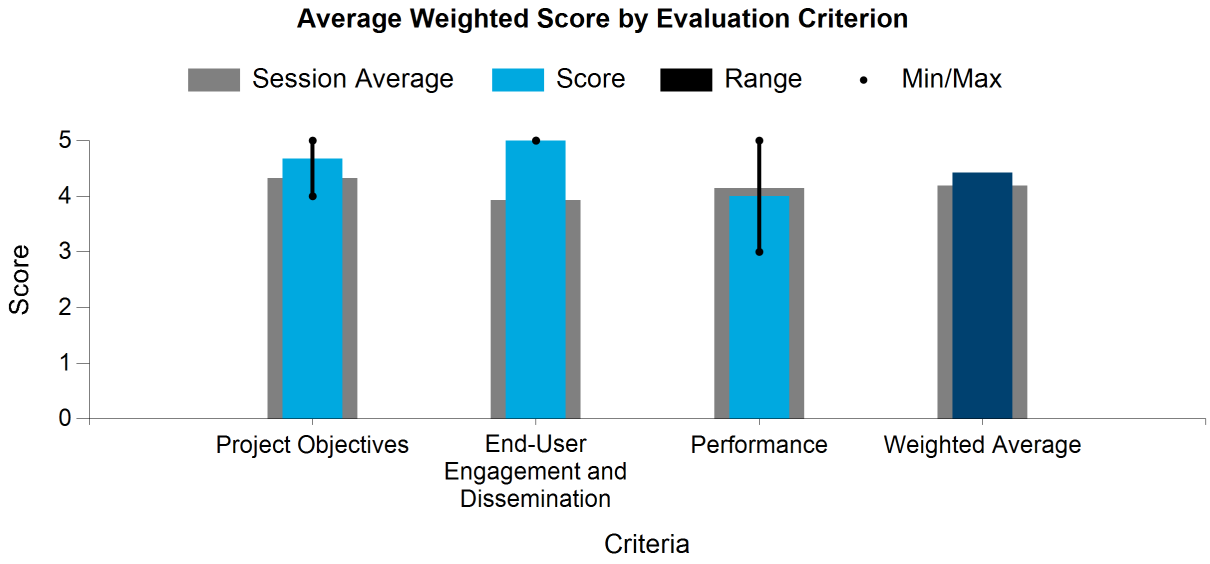
WBS:	EE0008954
Presenter(s):	Pukha Lenee-Bluhm
Project Start Date:	02/01/2020
Planned Project End Date:	04/30/2022

Project Description

This project's primary objective is to develop a standards-compliant, fabrication-ready, next-generation design of C-Power's StingRAY WEC. The H3 StingRAY will be designed for grid connection and at least two years of continuous testing and operation at the PacWave South test site. The design is intended to deliver an innovative, high-performance, survivable, and reliable device that is acceptable to potential customers, regulators, and other stakeholders, while also demonstrating the StingRAY's path toward cost-competitive electricity.

The H3 design builds upon C-Power's experience designing and testing WECs and is an iterative improvement of the previous H2 WEC design. C-Power's risk-driven design approach relies on conformance with relevant design standards, numerical modeling validated with scaled tank testing, and an iterative risk analysis process.

Clean, renewable marine energy is a challenging engineering problem but will be a critical component of climate change mitigation. The H3 is intended to service non-terrestrial loads—diesel genset replacement, at-sea vessel charging, larger-class remotely operated underwater vehicles and autonomous underwater vehicles, and others—and will be well placed for terrestrial applications when those become available. This project represents a key step to delivering the initial prototype for a later validation project and a practical and concrete step toward the future development of a larger utility-scale H3.



Aggregated Reviewer Comments

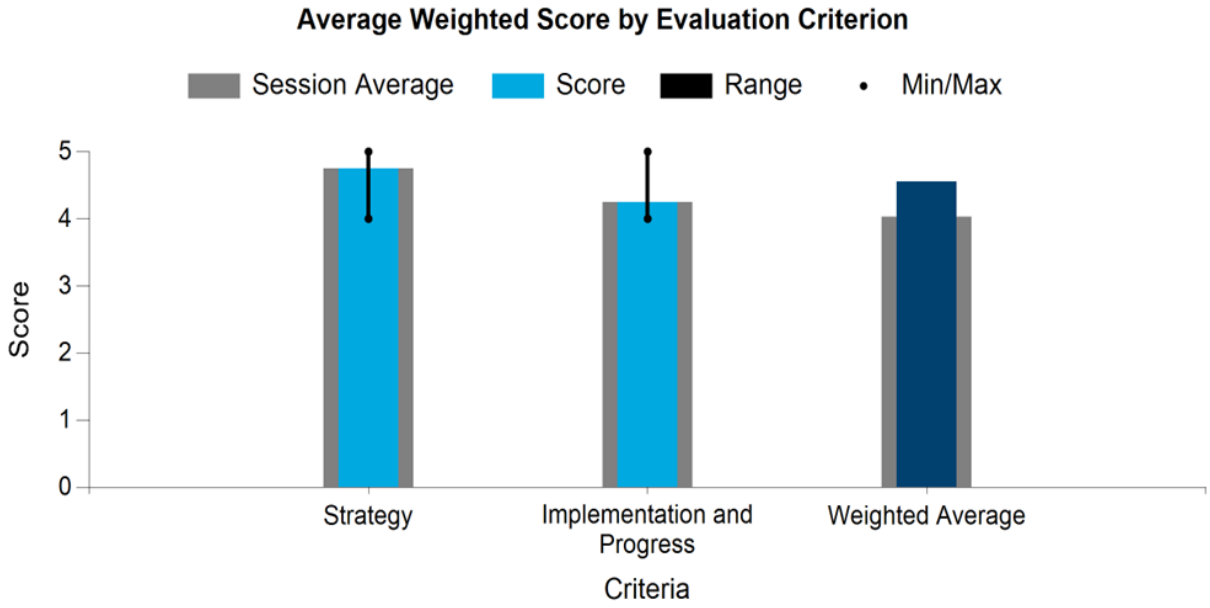
- The development of a design for near-term deployment at PacWave is well aligned with WPTO objectives. The project looks to scale up as experience grows (PBE first then larger scale later, representing a sensible approach to development). The project builds on previous project experience and learnings. There was no mention of lab or sub-system qualification testing of key components in the project plan or presentation generally. This may be worth considering to de-risk ocean operations further. Engagement with potential near-term users is being undertaken (though outputs or learnings are not known). The reviewer believes optimistic maintenance plans are in place based on remote and on-site maintenance for a first-of-a-kind prototype. Consideration for the unexpected is necessary at this stage and may be of benefit to the project.
- Objectives are in line with the program objectives. Dissemination activities seem to target the most important stakeholders. Regarding performance, it seems that all activities were in line with the objectives of the project.
- This is an interesting project that is an excellent fit with the WPTO program. They have a well-developed and thought-through plan. There is a good end-user engagement strategy and engagement with the user and their specific requirements. Performance and progress are all on track.
- This is a great project that is well executed. The end-user and potential customer engagement is very positive. It is difficult to evaluate the performance without some data or charts.

Reducing Barriers to Testing

Activity Area Evaluation

WPTO

WBS:	2.3
Presenter(s):	Lauren Ruedy



Aggregated Reviewer Comments

- Nothing to add.
- The Reducing Barriers to Testing Activity Area has a well-defined strategy to meet the specific challenges facing marine energy industry and stakeholders. The organization and rationale of the sub-activity areas and research priorities are well articulated, justified, and communicated. Most importantly, the work WPTO is doing and supporting is vitally and fundamentally important to the U.S. endeavor to advance marine energy production. The projects included in the Reducing Barriers to Testing Activity Area are well aligned with the stated goals and objectives from the MYPP. The breadth, depth, and contribution to reducing barriers that the projects represent are impressive, accelerating the opportunity for the United States to move toward marine energy generation and commercialization. The projects are generating real, measurable, and important results and deliverables. Just as important is the work of assembling and articulating project accomplishments and how they contribute to the marine energy community. In addition, the network of researchers of all types that is fostered by this large, government-funded program will leverage the advancements of any one individual project. The reviewer strongly recommends the development of a series of workshops to help bring the results of the breadth and depth of this work to researchers, developers, and regulators that are not actively part of the network formed by those within projects funded by WPTO. The advantages of such a series of workshops include the potential to accelerate uptake and commercial viability, reduce time to permitting, and enhance a wider understanding of the transferability of the technologies and methodologies tested and developed through this activity area. The work of this activity area is vitally important.
- The Reducing Barriers to Testing Activity Area is well run and is successfully addressing the objectives of the MYPP. The activity area manager understands these objectives and is executing a clear strategy to meet them. In accordance with the goals and objectives of the activity area, WPTO is funding many different areas

of technology that will reduce barriers to testing marine energy devices. These barriers are both physical locations for performing tests and permit acquisition for tests. To address these barriers, the activity area funds sensor development for measuring the environmental effects of marine energy devices to assist regulators in judging the permit applications for those devices, facilitates access to existing lab and field test sites, and is installing an open ocean test site. The portfolio of projects funded under the activity area demonstrates that the activity manager has a clear understanding of the needs of the industry. As stated above, the activity area funds projects that provide assistance to device developers in the testing of their prototypes in laboratory and field test sites. This testing assistance is accomplished through several projects, specifically Triton, TEAMER, National Lab and University Collaboration for MHK Instrumentation and Data Processing Tools, NMREC Infrastructure Upgrades, and PacWave. These efforts provide significant aid to marine energy device developers by supplementing their in-house expertise and providing test facilities, thereby accelerating the development and eventual deployment of renewable marine energy. Many of the efforts make use of leveraged funds from other sources. Individual projects are monitored by WPTO staff to ensure that taxpayer funds are properly spent, and schedules and milestones are followed as closely as practical. Inevitable delays, principally due to field tests facilities, are handled in an open and professional manner.

- The Reducing Barriers to Testing Activity Area does have a defined strategy that clearly reflects both the need of the program and the sector. There is clearly development for previous investments and work, which supports the ongoing needs of the industry. It is clear that the ability to test and validate not only marine energy technology but the devices by which performance and environmental impact are monitored, measured, and evaluated is a clear priority in meeting the MYPP. Of the nine projects within this activity area, there was a high degree of diversity ranging from the development of effective technology to monitor underwater sound and its impact to the delivery of a full-scale wave technology testing facility offshore. Only a very small number of project deliverables were not considered effective or were lacking in sufficient detail at this review stage to be determined as meeting the relevance and needs of the program. If all projects are able to overcome some of their delays, ensuring there is a broad and international dissemination of results and stakeholder engagement, then it is believed that the activity area is likely to meet its performance and objectives as defined in the MYPP.

Project Evaluations

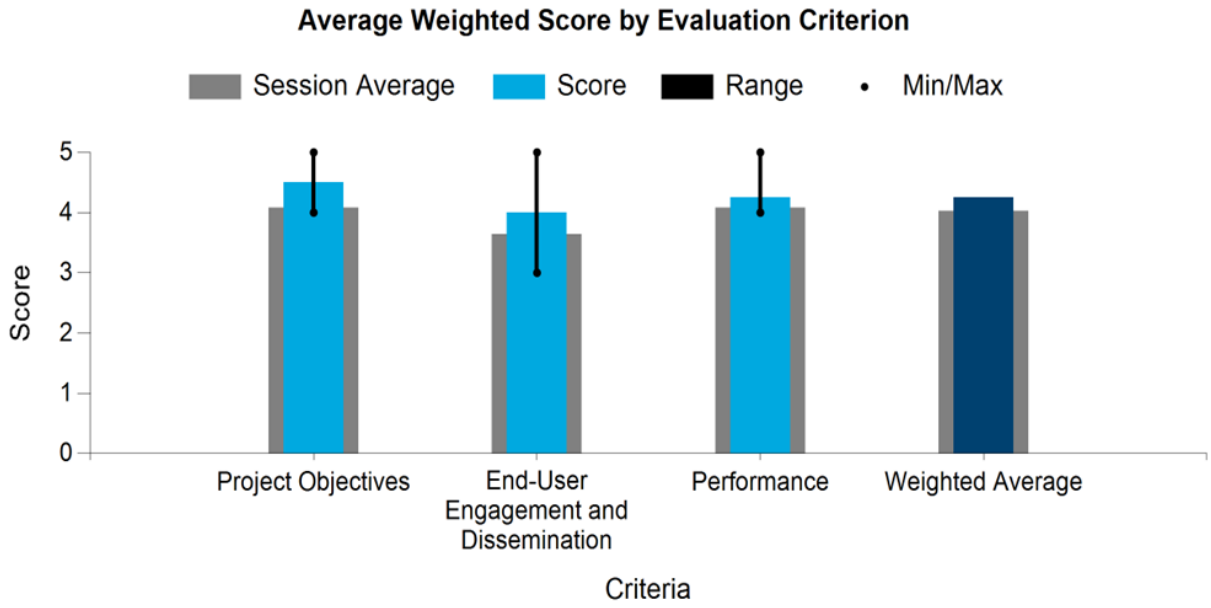
Triton Initiative

PNNL

WBS:	2.3.2.601
Presenter(s):	Joe Haxel; Garrett Staines
Project Start Date:	07/01/2015
Planned Project End Date:	09/30/2021

Project Description

The Triton Initiative is focused on reducing barriers to testing marine energy devices through R&D of technologies and approaches to improve understanding of potential environmental effects. Triton's evaluation of methods and instrumentation for environmental monitoring aims to address regulatory concerns and better inform decision making for permitting and licensing of marine energy projects. Triton's goals are to provide recommendations for economical commercial-off-the-shelf instrumentation for data collection, demonstrate recent improvements in technologies, and research and develop new tools to make environmental monitoring more efficient and effective. Triton works toward these goals by providing support for DOE-funded marine energy environmental monitoring technology development teams and performing in-situ, field-based demonstration and validation of commercial-off-the-shelf sensors. Triton has produced peer-reviewed and open-access publications, monthly subscriber newsletters, blog stories, social media, and website content, and presented webinars providing technical guidance, suggestions, and best practices for consistent and transferable environmental monitoring data collection and analyses at marine energy sites. Additionally, the Triton team collaborates with industry and academia to fill data gaps that improve overall understanding and reduce environmental concerns for permitting marine energy converters.



Aggregated Reviewer Comments

- Triton has a lot of "pots on the fire" with several different monitoring arrays over a large geographical area and with several institutions and labs. The combination of monitoring equipment to collect needed marine energy site dynamics and device stressor/receptor data is impressive. However, the cost effectiveness and the tremendous amount of data to store and transfer has yet to be seen for a long-term test in the open marine environment. The algorithms to pare down data to meaningful from clutter will have to be seen. If able to work

in unison, the monitoring suite could be effective and get solid, usable data to the end user without the need for massive data analysis. The tethered balloon system is novel but very dependent on perfect water clarity conditions and weather. The Probability of Encounter Model task has real potential for refining fish collision and interactions with marine energy devices and getting a massive volume of data to a usable end with far less time for analysis. Overall, Triton has great potential to provide a suite of environmental monitoring data, and some other WPTO projects (such as the Spatial Environmental Assessment Toolkit (SEAT)) and TEAMER could provide data analysis and outputs.

- High scores were awarded because the high-quality work produced directly contributes to the WPTO mission of reducing barriers to device testing. In this case, this involves barriers posed by the uncertainty in changes and risks to ecosystems presented by the introduction of these new technologies into the habitat. The work of evaluating, developing, and recommending approaches and technologies to establish ecosystem risk is particularly important in an effort to develop best practices in these specifically energetic environments. In addition, the project has initiated and activated a comprehensive framework for disseminating findings. Given the challenges to those on the frontline of the work of getting devices permitted, the central dissemination afforded by this multifaceted project is particularly valuable. Given the breadth of the projects associated with Triton, the reviewer was unclear which ecosystem components are still in need of testing or development of devices and approaches for measurement or monitoring. The one area for which the reviewer would like a deeper understanding is the translation from dissemination to uptake. The April 2022 article, One Size Does Not Fit All, is a recognition that the translation from dissemination to uptake is not straightforward. The reviewer suggests considering the development of a web-based, living document that contains decision trees that help the reader get to the right technology or approach to test, based on their site characteristics (biotic and abiotic), and act as a summary of the technologies or approaches tested and found to be less than a best practice (i.e., help the reader "rule out" as much as "rule in"). Within the appropriate boxes of the decision tree, references or links where the reader could find out more about the particular technology or approach would be particularly useful. Overall, the breadth, depth, and high quality of the work, publications, and dissemination efforts of this project are encouraging.
- The Triton project objectives contribute to WPTO's mission of reducing the barriers to testing by demonstrating an impressive quality and quantity of accomplishments in the project areas of FOA Support, Triton Field Trials, Environmental Technology Development, and Researching Stressor Receptor Interactions. The expected outputs of these projects will make significant contributions to future testing of marine energy systems by providing relevant data to regulators who will be making judgements on permits for those systems. The project timelines show well-defined and reasonable milestones for future work. The success of the work that has already been accomplished indicates that the project management team will be able to be equally successful for the future work. Regarding end-user engagement and dissemination, the team's Triton Communications Framework formalizes their process of communicating their many results to appropriate stakeholders. This includes 23 Triton stories published, 16 newsletters sent to 144 subscribers, 2,900 new website users, Triton Talks webinar series launched, and 178,000 impressions on social media. The team is also making a significant contribution to the Journal of Marine Science and Engineering special issue: Technology and Methods for Environmental Monitoring of Marine Renewable Energy. The reviewer did not identify any weaknesses.
- The project's objectives show clear alignment to reducing regulatory barriers and perceived risk to marine life from in-water marine energy devices. There are four key tasks within the project, each aiming to utilize off-the-shelf technology for improved data collection to inform collision risk assessment, underwater sound, marine species interaction with devices, and data processing with a focus on how to optimize data volumes and collection. The key output here is environmental monitoring package development for use with WEC deployments at the marine energy test site in Hawaii. The project also considers the collection of underwater sound data and monitoring utilizing a balloon above the water. Automated acoustic cameras will be utilized, which have been optimized to remove issues with field of view and will record image analysis. There have been

some delays to the ability to test the technology in a live environment due to delays in the deployment of WECs at the test site. Overall, this appears to be an incredibly useful review of available monitoring equipment, which seeks to optimize, refit, and rework the ability to collect data in the marine environment. The reviewer hopes that the processing aspect of the data, including seeking regulatory acceptance on the output, will be part of the ongoing program to 2024. It will be critical to ensure that the data and analysis are accepted fully by stakeholders to ensure the application of these novel equipment uses and optimization is fully utilized.

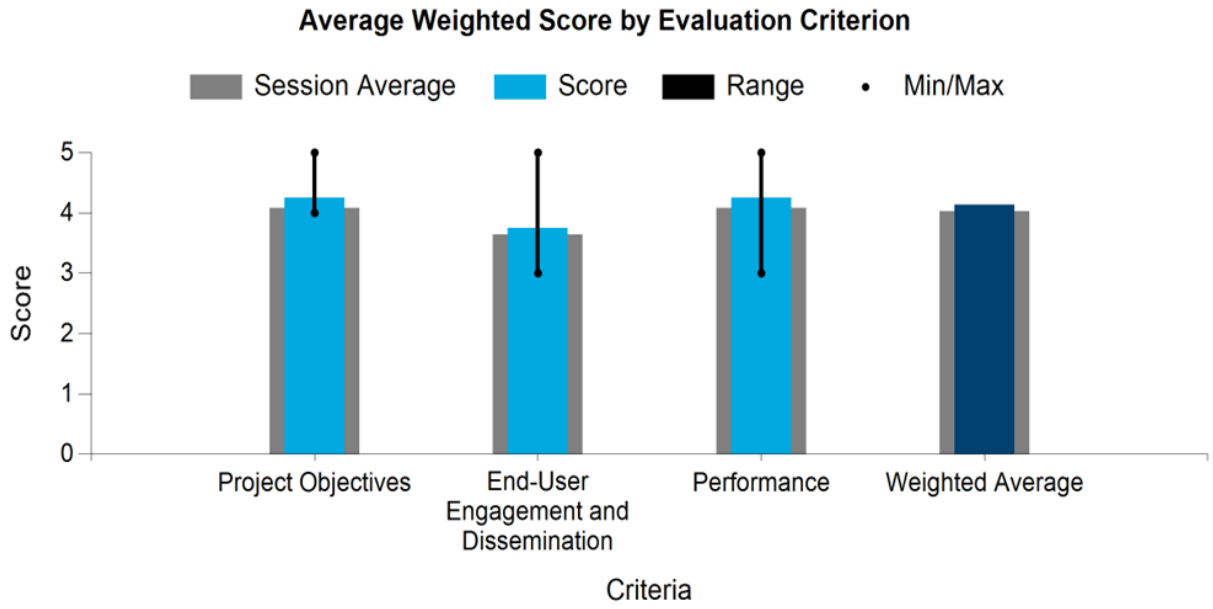
National Lab and University Collaboration for MHK Instrumentation and Data Processing Tools

NREL, PNNL, Sandia

WBS:	2.3.3.404
Presenter(s):	Rebecca Fao
Project Start Date:	10/01/2018
Planned Project End Date:	09/30/2021

Project Description

Field and laboratory validation, testing, demonstration, and operation are critical steps for increasing the TRL of marine energy converters because they provide high-quality testing and performance data that are critical to inform all aspects of technology development. This project, in partnership with industry, enables the MHK community to reliably and efficiently collect, process, manage, and share quality data by facilitating access to and development of instrumentation, guidelines, and data processing/quality assurance tools. Under this project, open-source data processing code and tools, instrumentation, data acquisition systems, and measurement guidance tools were developed to facilitate the collection and processing of quality laboratory and field data. Overall, this project is intended to improve the quality of the data collected during laboratory and field demonstration projects by standardizing the collection and processing techniques and by improving access to instrumentation, code, and measurement guidance. Quality data will, in turn, lead to improved knowledge capture following marine energy device testing.



Aggregated Reviewer Comments

- The National Lab and University Collaboration for MHK Instrumentation and Data Processing Tools project has good potential to reduce the analysis of data to usable data for developers and regulators on marine energy devices. The analysis of huge amounts of data for marine energy device monitoring can be a big barrier to a developer. The Marine and Hydrokinetic Toolkit (MHKiT) software system could greatly reduce this time and expense. The miniature data acquisition system sensor appears to offer real-time load sensing data to moored devices, but the reviewer is not sure if it is a barrier for marine energy devices' in-water use. Outreach also appears to be light and more along the webinar routes. This project and SEAT are of similar outputs and will help reduce barriers for in-water marine energy devices.

- This project appears to fill an important need for standardization and the development of standards for high-quality analysis of device readiness. The high scores are attributable to the clear articulation of needs identified (2017 workshop) and the solutions developed in response and to the list of engagement and dissemination categories. However, a quantification of the output within each of those categories would have been useful. From the contents of the last slide, the majority of the category of "Scientific Articles: Journal and conference articles and presentations targeting industry and academia have been published" appear to be conference presentations, leaving the reviewer with the impression that this portion is overstated and, therefore, makes it difficult to determine the impact of the other engagement efforts. The reviewer does recognize, however, the noted dissemination of MHKiT (11,000 downloads in three years).
- The project addresses three of the MYPP Marine Energy Program Activities: Program Activity 2: Technology-Specific System Design and Validation, Program Activity 3: Reducing Barriers to Testing, and Program Activity 4: Data Access, Analytics, and Workforce Development. The focus is on open-source software, which maximizes continued use by the marine energy community. Examples include MHKiT, Marine Energy Data Pipeline, and miniature data acquisition system posting on GitHub. User engagement is executed through knowledge hubs; webinars and workshops for industry, academia, and focus groups; journal and conference articles and presentations; industry and university partnerships; and news articles in industry publications. Various products will guide the industry toward standardized methods of data collection and reporting. Examples include the marine renewable energy code catalog, the Telesto knowledge base in PRIMRE, published guidelines for mechanical and PTO load sensors for larger-scale field testing, and a data quality control standards document. The reviewer did not identify any weaknesses or recommendations.
- The project will develop a suite of instrumentation guidelines and data processing/quality assurance tools to ensure that laboratory and field data is analyzed in a standardized way. A full logic model was included in the presentation, which was useful in determining how the project is considered in the MYPP. There were clear links to the program activity (including activities 2, 3, and 4), so the project clearly has relevance across the program. The standardization of data collection and analysis will be hugely important in the future development of marine energy projects by supporting the financial, technical, and impact assessments of viable projects. Providing open-source software tools makes the process highly accessible, and the focus should support broad dissemination. At present, social media and tutorials on YouTube are useful, but a more focused effort ensuring outputs are known and understood by the sector will be useful. The reviewer notes the output of 10 peer-reviewed papers, which is useful.

Improvements to Hydrodynamic and Acoustic Models for Environmental Prediction

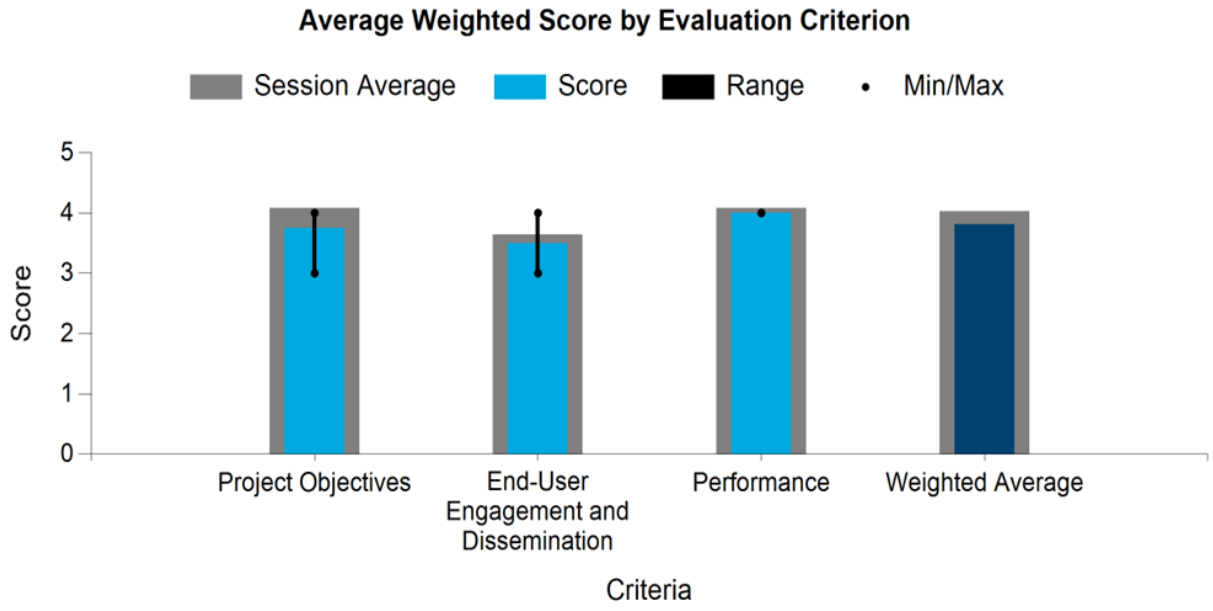
Sandia

WBS:	2.3.3.701
Presenter(s):	Jesse Roberts
Project Start Date:	10/01/2014
Planned Project End Date:	09/30/2025

Project Description

Successful development of marine energy projects will balance renewable energy production with risk to ecosystem health. Reducing environmental risk and permitting costs of marine energy projects can be supported with high-quality site characterization for site planning and better, a priori understanding of the potential environmental impacts associated with deploying marine energy arrays. Of utmost importance is for marine energy developers, regulators, and stakeholders to have the ability to plan marine energy array layouts that maximize energy production, support PBE applications, and minimize potential environmental risk.

Today, industry relies on disparate tools in project planning with limited effort or know-how to coherently coalesce results into actionable form. Tools that optimize marine energy production and ecosystem risk simply do not exist. Sandia is fulfilling this industry challenge by developing SEAT, which is made of linked, open-source, user-friendly models capable of characterizing marine energy sites and mitigating environmental risks associated with marine energy devices. The models characterize wave, hydrodynamic, and acoustic environmental stressors as a function of self-prescribed array specifications. Integrated into QGIS, SEAT creates a virtual laboratory to accurately assess and visualize environmental risk versus power generation. This allows developers, regulators, and stakeholders to effectively communicate with game-changing certainty.



Aggregated Reviewer Comments

- The SEAT project has the potential to provide a usable GIS data program for determining impacts on numerous stressor/receptor, geophysical, and acoustic parameters. This type of modeling would greatly help developers and regulators determine potential and actual impacts and the design of specific monitoring plans. Questions on validation of the data to modeling output could be of concern since there are no in-water outputs. Outreach

also appears to be light, and training and/or assistance in the use of the modeling software are unknown. Overall, SEAT has good potential to provide vital marine energy device environmental modeling for developers and regulators.

- This project is vitally important to the marine energy sector. It addresses the real need for a tool to quantitatively assess the potential impact of marine energy development and to serve as a visual and quantitative foundation to discuss and weigh the costs and benefits of development. The reviewer would have liked to have heard more about the investment of the human and data resources required to implement this tool at specific sites and the engagement and dissemination plans for meaningfully converting for updates and broad adoption. Overall, the concept of the tool is an exciting contribution.
- This project directly addresses Marine Energy Program Activity 3: Reducing Barriers to Testing by developing a comprehensive, multipart software suite that addresses several aspects of the planning process for a marine energy converter. The combination of wave, hydrodynamic, and acoustic models into one overall suite of models with GIS capabilities that can analyze WEC device specifics is a significant achievement. User engagement is executed through in-person workshops and demonstrations, conference presentations, peer-reviewed publications, and publicly available models and tutorials. Citation information would be helpful. This is a very useful planning tool; however, it is a combination of three sophisticated numerical models that cannot be verified or validated due to the lack of WEC or CEC arrays in the field. Therefore, some caution in its use is warranted. The reviewer could not understand many aspects of the presentation. For example, the legend and axis names are not explained (potential risk calculation colored bands on slides 11 and 12, the colored bands on slide 14, and the vertical axis of the bottom chart on slide one), and the erosion, deposition, and mobility information on slide 12 is difficult to decipher. The reviewer does not know what percent coverage refers to. It is not clear in the presentation which of the conference presentations, peer-reviewed publications, and publicly available models and tutorials via GitHub have occurred already or are planned in the future (except for the Offshore Technology Conference and model demonstrations for potential end-users noted on slide nine). The reviewer recommended improving the presentation of results for future reviews.
- The requirement to understand and manage the interaction and effect of marine energy devices on areas of marine resources (wave and tidal stream) is critical to the commercialization and acceptance of marine energy projects. The projects will use experimental tools to review resources and assess fluid-structure interactions and environmental risk at an array level through SEAT. The range of outreach and workshops to highlight the extensive nature of the tool was good to see, with engagement with the regulator as the end user and a common use of metadata. It would be useful to understand how the model will be verified when projects are live—in effect, how SEAT will perform against live, measurable data. Yield analysis and array interactions are two key areas of concern. In some cases, increasing arrays by a small percentage can have a significant effect on capacity factors in tidal environments. It would also be useful to understand how the model deals with the high degree of variability in the device types, which may require validation in the field. Clearly, the quality of the data being input will be key. While this was proposed as an area of key consideration, it was not demonstrated what quality assurance processes or decisions are made on data input. Overall, the project will be incredibly useful, especially as in validating demonstration deployments and extrapolating to array scale where there is a high degree of uncertainty.

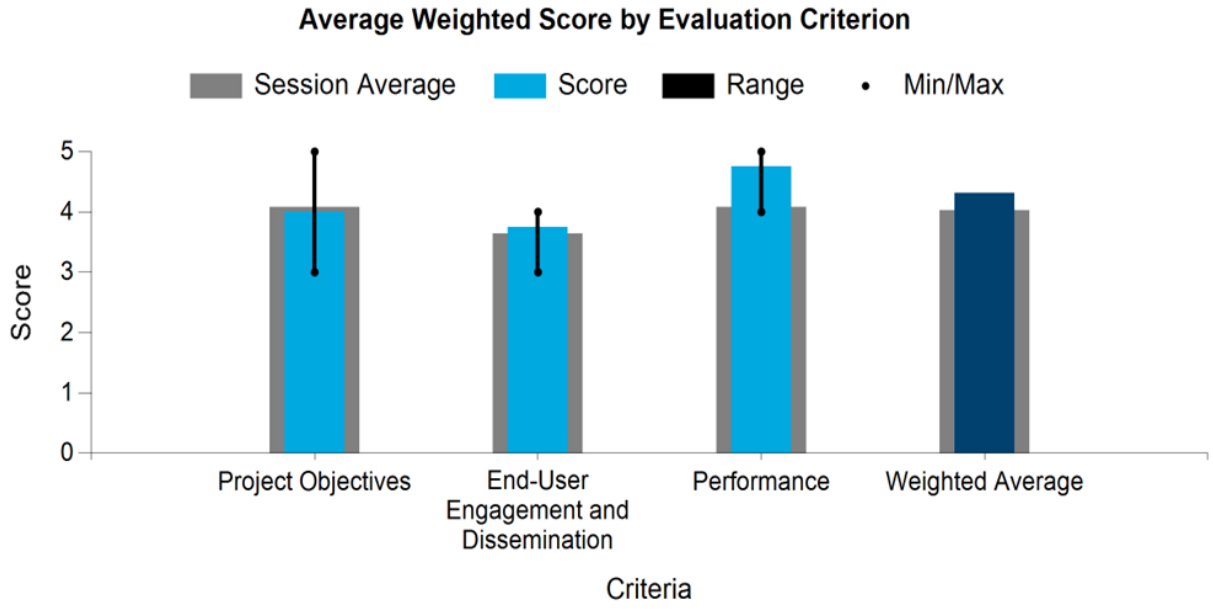
Rapidly Deployable Acoustic Monitoring and Localization System Based on a Low-Cost Wave Buoy Platform

Integral Consulting Inc.

WBS:	EE0007822
Presenter(s):	Kaustubha Raghukumar
Project Start Date:	12/01/2016
Planned Project End Date:	11/30/2021

Project Description

The primary objective of this project is to develop a cost-effective, fit-for-purpose environmental monitoring system that characterizes, classifies, and provides accurate location information for anthropogenic and natural sounds in real time. NoiseSpotter has been developed to support the evaluation of potential acoustic effects of MHK projects. By utilizing a compact array of three acoustic vector sensors, NoiseSpotter triangulates individual bearings to provide sound source localization, allowing for the ability to discern MHK device sounds relative to other confounding sounds in the environment while providing location estimates to nearby marine mammals for environmental mitigation purposes.



Aggregated Reviewer Comments

- The NoiseSpotter device appears to be an excellent, cost-effective means to collect marine energy environmental data and can be installed and removed quickly with a small commercial fish vessel. This device will provide quick, usable information for the industry and regulators to address environmental monitoring concerns pre-construction and when a device is installed. NoiseSpotter offers services with the device to support installation, recovery, and quality assurance/control data, providing an experienced, independent analysis of the data. NoiseSpotter has the best immediate and cost-effective means for providing focused data for developers and regulators on a marine energy device.
- This project provides an important advancement toward the potential to understand acoustic effects of marine energy technology introduced into marine habitats. It will be interesting to see the insights that this new device can bring to differing marine energy sites and devices. The reviewer came away wishing that the content of the Technical Performance Analysis table was presented in a form such that the important takeaways were more easily evident. The reviewer recommends the team consider breaking that table into multiple smaller tables of

focused content such as those categories relevant to gaining habitat insights, implementation considerations, and technical features. In addition, separating the score and comments into separate columns and using a color scheme that matches the legend would allow the reader to more readily skim through the scores of interest. The reviewer needs more explanation as to the meaning of "location estimation accuracy: bearing estimate within 2 m" given that bearing is generally a measure of direction.

- This project covered the successful development of the NoiseSpotter system, which measures the noise properties of marine energy systems, other non-marine energy noise sources, and acoustic particle velocities. All three data collections will be extremely helpful for environmental mitigation purposes and dealing with environmental regulators. The project included three rounds of in-water tests and numerous conference presentations and peer-reviewed publications. NoiseSpotter is patented and trademark registered, and the project came in very near original budget. The reviewer did not identify any weaknesses or recommendations.
- This project aims to optimize the extraction of sound data in the marine environment to enable better assessment of the impact of the deployment of marine energy devices in a live marine setting. The project is highly practical, having deployed the sensors in a range of environments, utilizing triangulation to allow MHK technology sound to be distinguishable from other marine and anthropogenic sounds. The project was presented with clear, logical relevance to the MYPP decision logic and was one of the few projects to clearly show the project program and go/no-go decision matrices. The project had considered not only the technical capability of the technology but also the associated costs, keeping deployment costs to less than $35,000 per deployment. The dissemination of the project has included some good, related peer-reviewed papers but will require additional end-user acceptance, particularly from a regulatory assessment process. While the data and methodology may show positives in terms of a test and validation environment, there should be clear links and engagement with end users to ensure the data outputs can be used to remove regulatory risk. The operational environments, including tidal sites to 2.5 meters per second and wave environments up to 2 meters at 15 seconds with a depth of almost 200 meters, appear to cover a wide range of applicable marine energy sites; however, more testing will be required to fully assess reliability and risk in deployments in energetic and diverse marine environments.

Long-Range Target Detection and Classification System for Environmental Monitoring at MHK Sites

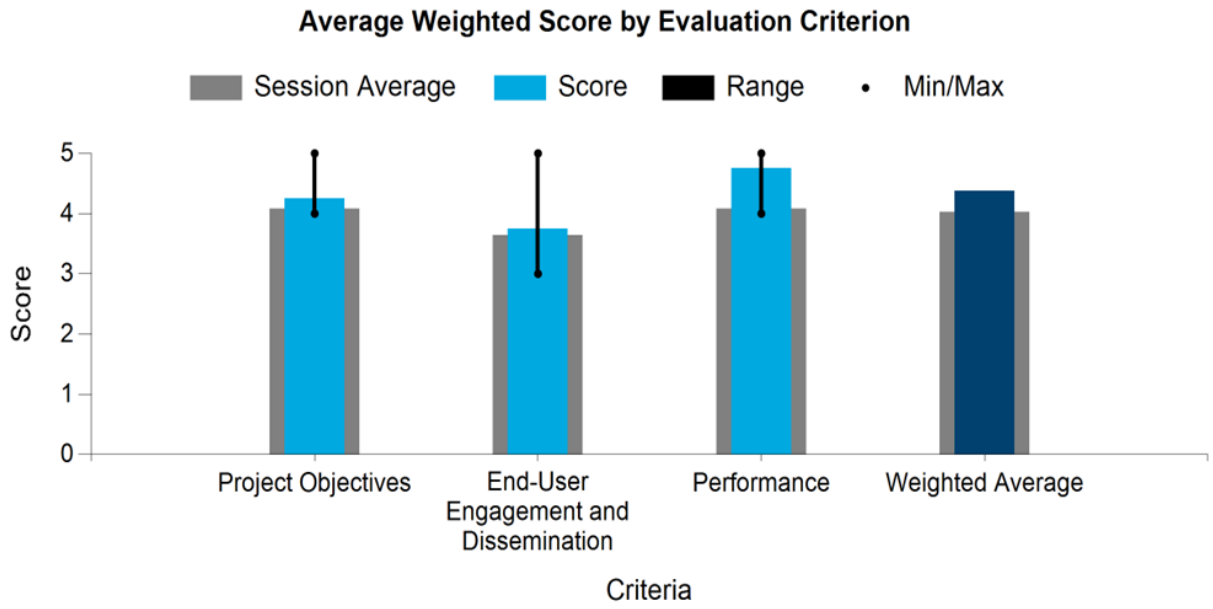
Biosonics, Inc.

WBS:	EE0007824
Presenter(s):	Tim Acker
Project Start Date:	01/01/2017
Planned Project End Date:	06/30/2022

Project Description

Marine energy developers, regulators, and the public need to understand how candidate marine energy devices affect the behavior of fish, marine mammals, and other marine life for responsible project permitting decision making and to provide an early warning of anomalous or dangerous marine life activity. This automated target detection, localization, and classification system will help answer key questions including whether the presence of a marine energy device alters the natural migratory and/or foraging behavior of marine mammals and other migratory species by repelling or attracting these animals, and whether marine mammals become entangled in marine energy device mooring cables. By unobtrusively monitoring marine life behavior before, during, and after marine energy device installation, this technology helps to further understand the potential environmental risks to marine organisms from devices.

The goal of this project is to deliver a practical, robust, and cost-effective long-range (200 to 300 meters) active acoustic monitoring system with innovative, shaped pulse-and-chirp capabilities to suppress off-frequency sound energy within the hearing range of marine mammals to automatically assess marine life behavior at marine energy sites. The one-of-a-kind sonar system successfully integrates a 360-degree perimeter detector to automatically detect and geolocate targets at range and a focused split beam directed classifier to track and classify target types.



Aggregated Reviewer Comments

- The BioSonics device is unique in marine energy environmental monitoring by being able to identify and track targets in a somewhat far field area around a marine energy device. The combination of active and passive sonar with real-time reports could greatly reduce barriers for testing and monitoring and provide usable, quick data to developers and regulators for informed decisions on device placement and monitoring plans. The noise

reduction and ability to lessen background noise clutter and target detection down to the size of a herring out to close to 150 meters is impressive. Go/no-go decisions were met early. Outreach to industry and end users seems to be light and in the works. BioSonics, similar to NoiseSpotter, has good immediate and potentially cost-effective data for its end users.

- This project looks very interesting. There is intriguing acoustic engineering to reduce the signals at frequencies overlapping with marine animal vocalizations and reducing the amount of time the energy is in the water at any particular direction. The reviewer would have appreciated reporting on the site and target characteristics required for this technology to be viable out to the hundreds of meters reported and, in the interest of uptake, the price to implement this system. In addition to potential cost, it is unclear to the reviewer how the output from this system will be actionable or used in the quantification of risk to ecosystem components. The tracking demonstration included one target. The reviewer inquired how the output of the system will be used/useful in a region of high biological presence and activity. The reviewer's main concern in the project objectives category is the transition to uptake. Where applicable, the ability of this technology to synoptically track directional movement will enhance regulator and stakeholder understanding of habitat use.
- This project directly addresses Marine Energy Program Activity 3: Reducing Barriers to Testing by developing an active acoustic system that monitors marine-life behavior near marine energy devices. This capability can document the effects the marine energy device has on marine life. The data collected will be crucial to regulators who issue permits for marine energy devices. The project successfully achieved go/no-go 1 and 2 milestones. A project strength includes reduced sonar frequency transmissions in the hearing range of marine mammals. This allows the behavior of marine mammals near the marine energy device to be attributed to the marine energy device and not to the sonar system itself. The project successfully tested the prototype system on the seabed at the PNNL Marine Sciences Laboratory test site, which included tracking man-made targets. The time series echogram shown on slide 13 shows successful natural cluttered background removal. The six-month field deployment with the C-Power SeaRAY and SAAB unmanned underwater vehicle docking station at WETS in Hawaii is an excellent test of the system. User engagement was executed via conference articles and presentations. Regarding weaknesses, the reviewer did not notice any journal papers. The reviewer did not have any recommendations.
- The project aims to improve long-range target (marine species) detection and classification using Biosonics' existing technology. The project would produce outputs including biological species classification out to a 360-degree perimeter with successful suppression of low frequency sound. The device would be powered by coupling to a deployed (and presumably operational) marine energy device, and the project demonstrated a clear and understandable project plan with reference to how the go/no-go decisions were made within the project. It is understood the project has been subject to some delays due to the anticipated deployment of a marine energy device (WEC) at WETS. The data will be used alongside direct classifier and behavior-based classification to determine types of marine species interaction with devices. Clearly, from a regulatory perspective, development of classification algorithms to ensure a high level of confidence in type of marine organism (pelagic fish, cetacean, etc.) will be key as will species-level identification to ensure that key species or receptors that have a particular conservation value can be identified. Further work should focus on risk identification and mitigation given the device will be closely linked to marine energy devices. It would be useful to undertake extensive end-user engagement with a range of technologies and applications to ensure technical compatibility and uptake.

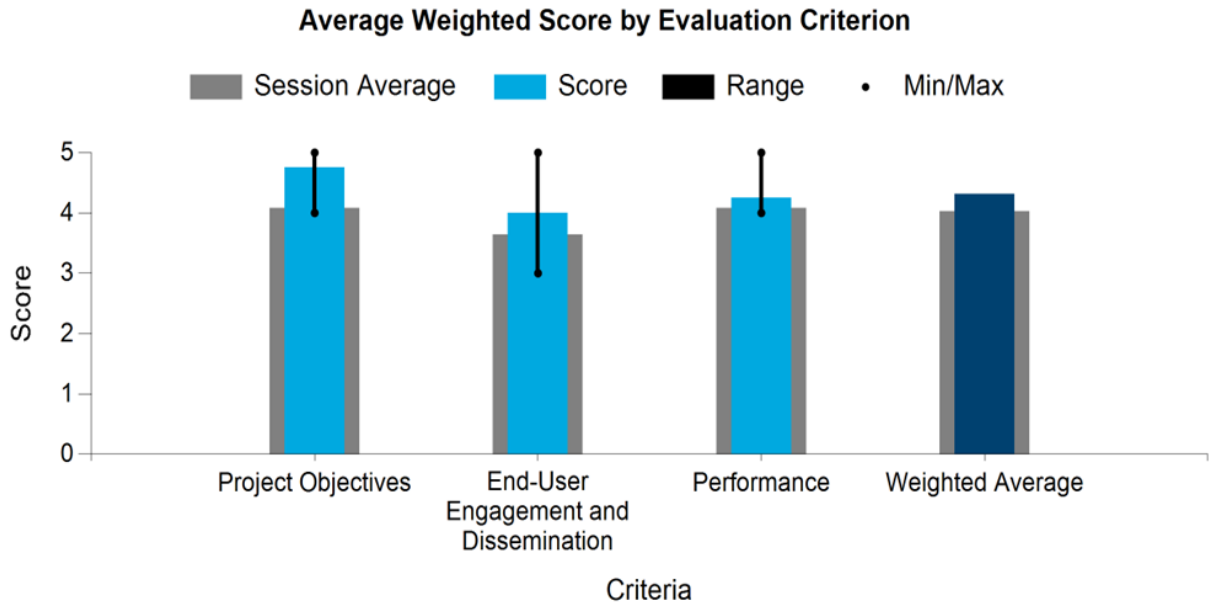
Enabling Cost-Effective Electricity from Ocean Waves: PacWave

Oregon State University

WBS:	EE0007899
Presenter(s):	Burke Hales
Project Start Date:	05/01/2017
Planned Project End Date:	07/31/2023

Project Description

PacWave South is a fully energetic, pre-permitted, utility-scale, grid-connected wave energy conversion test facility that is currently under construction. Located in 75-meter water depth, 7 miles offshore southwest of the port city of Newport, Oregon, PacWave South will offer four independently cabled test berths with subsea power transmission cables, each rated to 5 MW at about 35 kilovolts. PacWave recently completed underground construction of the conduits in which the power and data cables will be installed and the connection vault where the subsea and terrestrial cables will join. Negotiations for subsea cable procurement and installation are underway, and the request for proposals for a shore-side power-conditioning and data-collection facility is near release. When complete, PacWave will offer accredited testing of a range of WEC devices via relationships with partner agencies. PacWave will be a first-of-its kind facility in North American waters and will reduce barriers to testing a wide array of WEC and monitoring devices.



Aggregated Reviewer Comments

- This project has good fundamentals as a WEC regional testing site with potential to provide excellent in-water device data collection for functionality, environmental monitoring, and power delivery. Concerns related to getting the cable infrastructure installed and the availability of cable and support ships for installation were well noted and understood time delays and impacts to getting PacWave up and running. The lack of established universal mooring is concerning as a barrier to any end user with increased cost and permitting requirements. It is unknown if there is a business for costs to use the facility. Overall, this project will meet vital needs for testing in-water WEC devices under a variety of conditions and conducting environmental monitoring for marine energy moving forward.

- The presentation was well done and well received. The content was sufficient to convey the importance, vision, and contribution of the project. The reviewer was really struck by the magnitude of the challenges faced and not yet done with in an effort to bring this important project to completion. The end-user engagement/ dissemination score is reflective of the fact that the transfer to commercialization once the project is complete is not yet in place. From the conversation during the question period, it sounds like this is something that is already being thought through while still attending to the very large and very real immediate infrastructure needs.
- This project directly addresses Marine Energy Program Activity 3: Reducing Barriers to Testing by providing a pre-permitted, grid-connected, open-ocean, high wave energy test site for marine energy developers. This will accelerate the development of marine energy devices. The license application is a significant step. It is not clear from the presentation whether the license has been awarded. Accreditation to developers is an interesting concept. It was unclear to the reviewer who awards the accreditation. Significant progress was demonstrated with the release of the cable request for proposals, completion of the underground construction at the park, and the completion of the four beach-landing, horizontal directional drilling bores and conduit installation. User engagement is executed through engagement with local stakeholders and agencies. PacWave is also coordinating with DOE awardees for use of the site. The reviewer did not identify any weaknesses. The reviewer recommended that the cable design-build contractor should have ocean cable experience. Based on sketches of the PacWave site, there will be several miles of ocean cable from the seaward exit of the beach-landing conduits to the subsea pod. Some form of protection (burial, armoring) is essential. The seafloor cable industry has much experience in these methods.
- The PacWave facility will be the first of its kind in U.S. waters to allow for testing and small demonstration arrays of WECs. The four berths, with a total facility capacity of 20 MW, will be cabled to shore and allow WECs to be tested, measured, and accredited at the site. The projects' locations, some 7 kilometers offshore in a high energy environment, has resulted in cables being laid in conduits, which have been constructed. The ability to install and pull the cables will be high risk and require significant risk mitigation. It would also be useful to consider the business model for continuation of the site and potential upgrades. Monitoring of economic activity, gross value added, and associated societal benefits from the test site should also be recorded carefully to ensure value for money. It will be useful, when the site is operational, to run a lessons learned workshop and look at how operational data and experience can be shared more widely with the sector. It was not clear if users of the site were engaged in the process or if end users had been identified; however, it was assumed that this was the case. The completion of PacWave and the installation of wave energy devices on the West Coast of the United States offer enormous potential to accelerate the development of wave energy technology and the associated innovations. It has the potential to yield useful and verifiable data and knowledge on the performance, impacts, and value of wave energy. The results and activity at PacWave should be widely disseminated.

Network Director for the Testing Expertise and Access for Marine Energy Research (TEAMER) Program

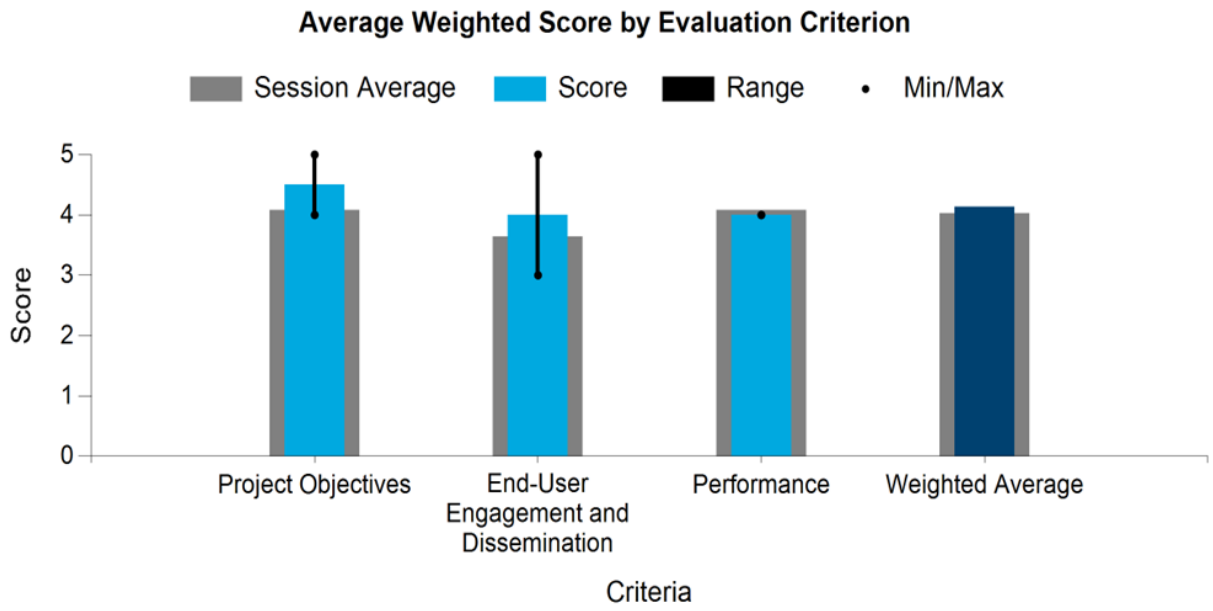
Pacific Ocean Energy Trust

WBS:	EE0008895
Presenter(s):	Matt Sanders
Project Start Date:	12/01/2019
Planned Project End Date:	11/30/2024

Project Description

Marine energy device developers and researchers are constrained by the cost of and limited access to device testing facilities and specialized numerical modeling and engineering expertise, particularly during the early stages of technology development. The TEAMER program was initiated to address that challenge for technology developers and researchers by providing easy access to testing infrastructure at qualified facilities at minimal cost and in a timely manner, leveraging world-class expertise and testing support from the nation's leading marine energy experts, and contributing to the marine energy community's knowledge base by providing lessons learned and post-processed test data to a repository that will serve the industry as a whole.

TEAMER is unique by offering regular and repeated opportunities for assistance, making it a one-stop shop for browsing and comparing U.S. marine energy facilities that have opted into the network and a hub to collect lessons learned, share outcomes and best practices, and converge on key standards and norms. Outcomes for TEAMER will include reduced iteration cycles for developers using TEAMER, quick and efficient access to testing infrastructure and expertise for design and device evaluation, and increased collaboration between technology developers and foundational research institutions.



Aggregated Reviewer Comments

- The TEAMER project appears to be an overarching regional manager of facilities for researchers and developers for testing of devices. It is unknown if there is an issue to access for established labs and test facilities, and it appears to be a networking connection for developers and researchers with facilities. It does not appear TEAMER reduces the costs for environmental monitoring since open-water testing facilities most likely have some form of umbrella federal and state environmental permits. TEAMER has 34 facilities with more than 100

different capabilities but only offered seven requests for support from 2020 to present of which all appear to be lab/flume tank projects. No open-water requests for support occurred. Actual outreach for end users is unknown.

- The project is impressive in its breadth, reach, and value, and its relevance to the marine energy community was well articulated in the presentation. The reviewer congratulated the program on the extended network of developers and organizations supported to date. The reviewer recommended considering the addition of webinars about the projects to the list of dissemination activities.
- This project directly addresses Marine Energy Program Activity 3: Reducing Barriers to Testing by providing a formal mechanism (requests for technical support) for marine energy developers to gain access to specialized expertise and testing facilities. This will accelerate the development of marine energy devices. Support provided by TEAMER Facility Network members (numerical modeling and analysis, laboratory and bench testing, tank/flume testing, and open-water testing and support) is crucial to the successful development of a marine energy device and is the type of specialized expertise that developers are unlikely to have in house. The program also helps the TEAMER Facility Network members maintain and sharpen their expertise and support faculty and students. The success of the program is demonstrated by the 78 projects currently supported through six requests for technical support noted on slide 10. Other indicators of success from slide 10 are the 49 technology developers/organizations supported and the 25 organizations supporting current requests for technical support. The 74% TEAMER Facility Network member utilization rate is a healthy number, and it is good to see that the TEAMER network director will work to increase it in the future. User engagement is executed through workshops and training opportunities. The reviewer did not identify any weaknesses or recommendations.
- The TEAMER program is an effective way to ensure that there is a good understanding and collaboration between test facilities in the United States. It provides testing expertise and access to facilities for marine energy research. The program also looks to leverage world-class expertise and provide a repository for lessons learned. The process includes a request for technical support and has had 34 applications so far. There is a clear focus on wave energy technologies, which is indicative of prevailing technology development in this geographic region. There was a lack of clear go/no-go frameworks; however, a strong project plan was presented. It would be useful if more end-user engagement was undertaken to strengthen the experiences and knowledge generated by beneficiaries of the TEAMER program. It is important to note that the premise of providing this sort of coordination and access will reduce cost, time, and risk to developers of devices and components and remove duplication of capital spend on areas that have already been investigated. This is positive, but the team should ensure there is broad dissemination of the capacity of the project to deliver. National-level coordination of data, knowledge, and expertise should support technologies at low TRL levels and also potentially remove barriers to project development. It will be critical to ensure there is a legacy here and that repositories and databases are well used by not only the request for technical support applicants but the broader marine energy sector and stakeholders.

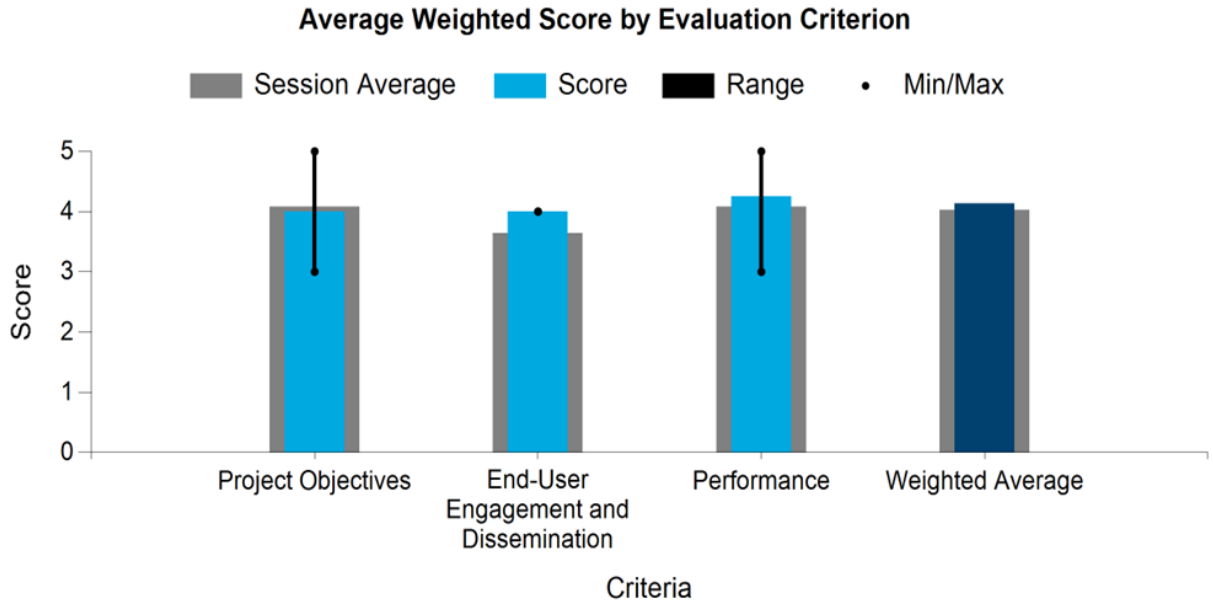
National Marine Renewable Energy Center Infrastructure Upgrades

University of Washington

WBS:	EE0008955
Presenter(s):	Brian Polagye
Project Start Date:	04/01/2020
Planned Project End Date:	03/31/2023

Project Description

Since they were established in 2008, the NMRECs have supported a wide range of research, development, and testing in collaboration with academic, national laboratory, and industry partners, leading to outcomes that have advanced the foundational understanding of marine energy systems. The wide range of upgrades being undertaken across institutions affiliated with a NMREC are intended to maintain and expand that research capacity in response to end-user needs. These upgrades include new capabilities that address gaps and "pain points" in existing infrastructure, replacing infrastructure that has reached the end of its service life, and forward-looking investments that support the next generation of student researchers. When complete, these upgrades will enable research to understand the fluid-structure interactions for multiple types of marine energy converters, expand the range of conditions that can be generated in laboratory experiments, reduce barriers to testing marine energy systems in open-water environments, and facilitate testing of marine energy systems with blue economy applications.



Aggregated Reviewer Comments

- This project has identified gaps in marine energy industry needs for WEC and CEC devices both in laboratory and open-water infrastructure. Each NMREC had vastly different needs and capabilities. These upgrades seem to be more designed on the academic end than for specific end-user/industry needs in reducing barriers to device testing and monitoring. These upgrades have more to do with R&D than providing necessary testing data for device monitoring and reducing barriers for in-water grid devices. The identification and outreach for end users/industry are light and more regionally based, and there appears to be some overlap with other WPTO projects. This project is focused more on infrastructure needs for marine energy R&D and laboratory testing; yes, it will potentially reduce barriers for developers but will have more of an academic research use.

- It would have helped the reviewer to have some sense of the breadth of the need fulfilled by each of these upgrades and a clearer understanding if the upgrades fulfill a need versus a gap. It was unclear to the reviewer whether the outreach to identify gaps and needs was sufficiently broad so as to include representatives of industry. The presentation indicated that it was the universities affiliated with NMREC that collaborated to identify the infrastructure priorities. The efforts identified as internal capacity building are important and well selected as are the end-user engagements as this project moves to completion.
- This project directly addresses Marine Energy Program Activity 3: Reducing Barriers to Testing by working with all the NMRECs to improve facilities available to marine energy developers. By establishing a coordination mechanism among the NMRECs, the duplication of capabilities is minimized and each NMREC can improve its area of expertise. This makes the best use of scarce development funds. Gaps were identified first to ensure selection of the most useful upgrades. Upgrades were made to laboratory, computational, and field capabilities and an equipment pool of environmental sensors. New capabilities are already being used at the Tanana River test site of the University of Alaska Fairbanks. Another strength was the coordination with TEAMER to make new capabilities available to developers. User engagement is executed through coordination with TEAMER, conference presentations, and webinars. The reviewer did not identify any weaknesses or recommendations.
- The NMRECs include five universities within this project that are upgrading, enhancing, and future proofing their facilities in response to end-user needs to support marine energy systems research. The receiving institutes reviewed both their own capability gaps and feedback from end users to identify key areas of enhancement. It is understood that there have been some delays in facility upgrades due to the global health pandemic with some underspend attributable to issues with larger fabrication delays. The project is associated with TEAMER, which should ensure significant uptake and use of the facilities. The tasks within the project are not serialized, and the project should consider how risk management can be effective in the program. It would be useful to also future proof the facilities to consider not only wave technology, components, or monitoring equipment but also any new and innovative blue economy solutions that may be able to make use of the facilities and infrastructure. The project should ensure that its outreach is not confined to academic peer review but is extensively disseminated across the industry, stakeholders, and potentially other areas of blue economic development. This should help maximize the use of the facilities and potentially create longevity in the project.

Current Turbines Mobile Testing Vessel

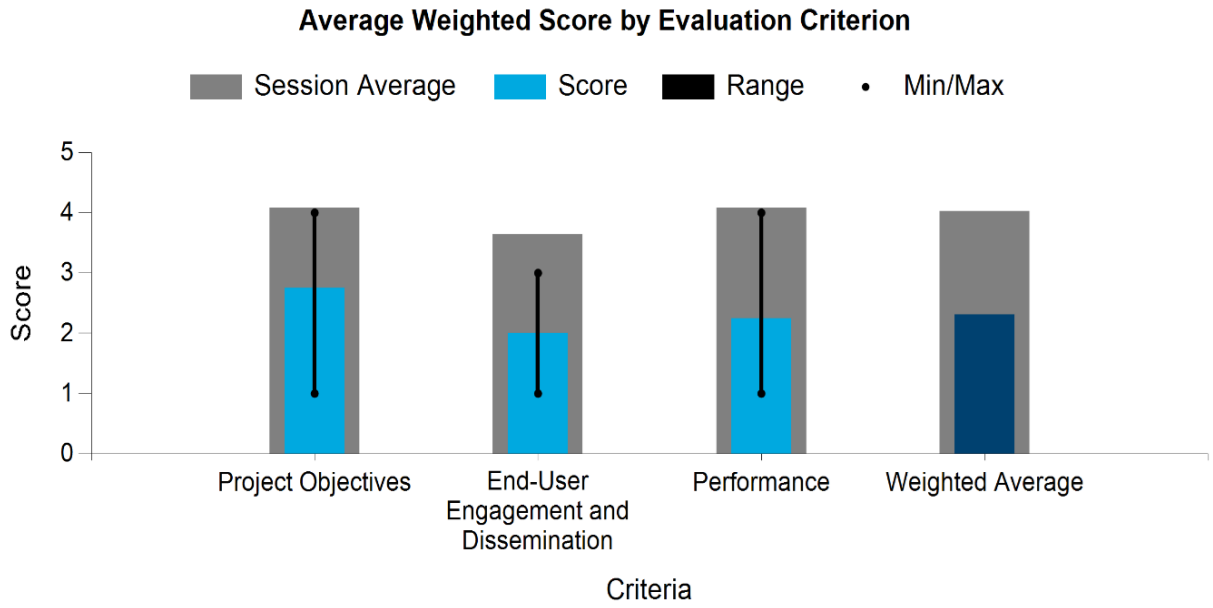
Idom, Inc.

WBS:	EE0009452
Presenter(s):	Alvaro Garcia
Project Start Date:	10/01/2021
Planned Project End Date:	03/31/2023

Project Description

As the marine energy industry continues to advance technologies toward commercialization, there is an ongoing need for testing at all stages of development. The slow pace of design and in-water testing cycles is further exacerbated by the limited availability of testing infrastructure at various scales, complex and time-consuming permitting processes, and expensive environmental monitoring. These challenges have limited the ability of turbine technology developers to assess the performance of devices and components, innovate solutions where necessary, and deploy the next generation of devices. CEC prototypes must be tested in real-world environments to fully characterize and validate the performance, reliability, maintainability, and potential environmental impact. Existing U.S. testing infrastructure can only accommodate small-scale CECs with rotors between 2 and 3 meters in diameter. There is a need for a mobile testing capability that can accommodate CECs with up to 8-meter diameter rotors for testing turbines in a wide range of conditions.

With the aim to help propel the development of marine energy technologies toward the commercialization phase, this project is aligned with DOE's objective of filling the gap on testing infrastructures for CECs in real conditions at large scales. It enables developers to be focused on technology development and power performance-related issues, offering a mobile test vessel that can be shared since it can be easily transported to different sites depending on the end-user needs. This will help reduce the cost of technology development associated with testing, infrastructure, and foundations. This project aims to design, test, fabricate, and operate a mobile test vessel to be used as mobile test infrastructure for CECs.



Aggregated Reviewer Comments

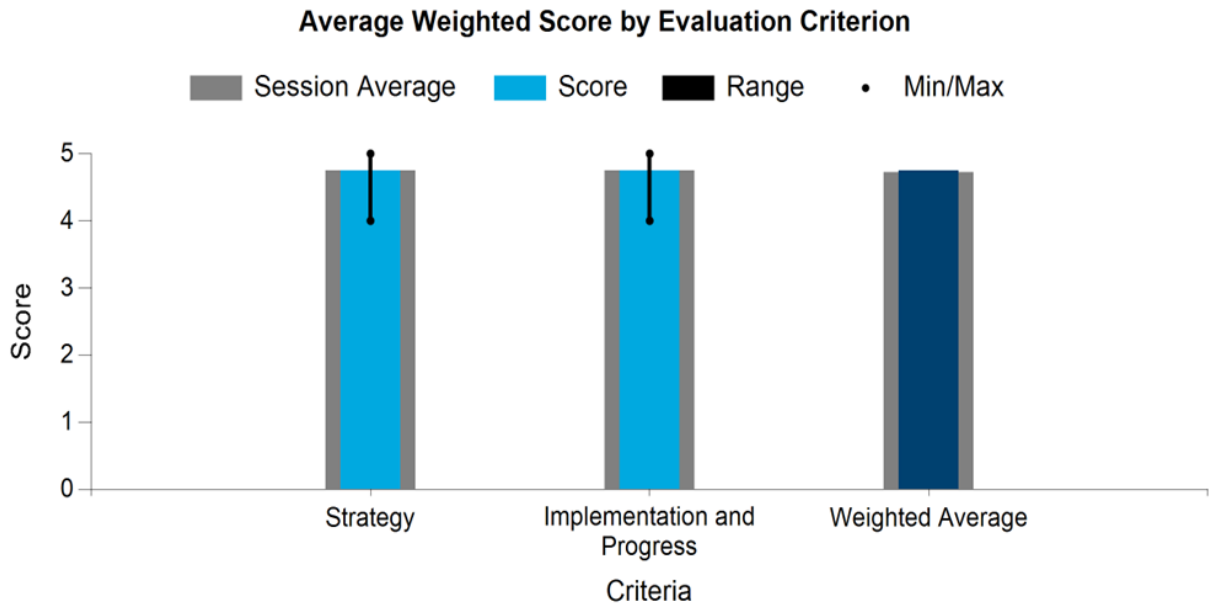
- This project has identified the points of go/no-go well on its timeline and a well-thought-out objective approach for the design of the project. They have identified possible and potential gaps needed for testing marine energy CEC devices; however, the identification of needed end users/industry is lacking along with the adaptability of the vessel to different CEC devices, use/transport to specific study areas, and who would bear the cost of use. Additional barriers would come up for different sites such as mooring systems, National Environmental Policy Act, and USACE and state regulatory environmental permitting. There are critical concerns with this project on end users, adaptability for device testing, mobility to locations for device testing, and costs associated with all aspects (such as O&M, crew, and berthing).
- The low scores for this project are a reflection of the fact that while the project is intriguing and interesting, it was not sufficiently clear that the project fulfills a need articulated by the marine energy community. The presentation of the project objectives, approach, and timeline were helpful in understanding the scope of the project and its undertaking. However, although the concept of a mobile testing platform is intriguing and is a gap in the current availability of testing infrastructure, the end-user interest for such a project has not been identified or sufficiently articulated, and it is unclear if the project fills a need (as opposed to a gap). Given that use of the platform would require additional engineering by the developers, the cost-benefit of this project needs to be clearly articulated along with the costs, additional engineering, and fabrication for connectors for developers to make use of such a platform and indicate that this is the right solution for testing large turbines.
- This project directly addresses Marine Energy Program Activity 3: Reducing Barriers to Testing by developing a craft to facilitate the testing of CEC technologies. It also allows for convenient environmental monitoring. Collected data will be uploaded to the MHK data repository. This will allow the entire marine energy community to benefit from the results of this project. The project approach is logical and well considered as described in the specific items listed under the conceptual, preliminary, and final designs of budget period one. The division of tasking of the key stakeholders is comprehensive. Regarding weaknesses, the reviewer inquired if the test vessel has enough customers. Comprehensive user engagement is required. The reviewer also inquired if the vessel will be able to accommodate a wide variety of CECs. The reviewer recommended the team select a competent naval architecture firm with experience designing vessels for the ocean environment.
- The project has recognized the need for testing infrastructure for tidal energy convertors (or CECs) by proposing the design and construction of vessels that will have the capability to test turbines in the range of 2 meters to 8 meters in diameter. This is a three-year program that started in the 2022 fiscal year. The project has a very clear decision process and project plan, which was well articulated. It is understood that conceptual design is ongoing; this should be very closely linked to end-user requirements. It was not clear how many end users had expressed a requirement for the facility or how the diversity of tidal energy environments (including turbulence and other site-specific issues) could be better understood by utilizing a vessel such as this design. If there is uptake, the vessel could be useful in reducing the timeline of design iterations in multiple tidal flow devices and could provide the ability to validate cost and performance; however, it is not yet clear if this is achievable.

Marine Energy Data Access, Analytics, and Workforce Development

Activity Area Evaluation

WPTO

WBS:	2.4
Presenter(s):	Allison Johnson



Aggregated Reviewer Comments

- Regarding the strategy, the program has a defined strategy that reflects both the needs of the industry and the stakeholders and challenges faced. The key results from each of the four activities—especially around testing of devices both in the lab and on site and improving regulatory efficiencies—are key to move the industry forward. Focusing on the Data Access, Analytics, and Workforce Development projects, while all the projects are very impressive with useful outputs being produced, at the moment there is not enough evidence that these projects have resulted in improved regulatory efficiencies or reduced uncertainty around environmental impacts from a regulatory perspective. Moreover, it is not clear if the tools/methods created in these projects are likely to be widely implemented in the future for decision making. However, this might be due to the early stages of the projects given that all the tools have a huge potential to streamline permitting and licensing if widely used by developers and regulators. Specific to the Workforce Development projects, it is unclear if the program will attract people who do not have a previous interest in the area or knowledge of the field. It would be useful to clarify with whom the resources are being shared.
- The scope of the Marine Energy Data Access, Analytics, and Workforce Development program is well aligned with the objectives of WPTO's MYPP. Tools developed through this project, like PRIMRE, provide relatively easy access to data and information for end users (e.g., researchers, developers, and regulators) that would otherwise be difficult to locate and compile. In doing so, this project facilitates the development of the marine energy sector in the United States and assists in the global expansion of innovations that are needed to ensure a sustainable transition of our energy supply to marine renewable sources. Crucially, this work has been informed by prior engagement and consultations with industry and stakeholders and incorporates feedback from these groups in addressing sector needs. The workforce development aspects of this project (programs, products, outreach, etc.) are also of tremendous value for the future expansion of the marine energy sector. Overall, this program is well aligned with WPTO's overall strategic direction.

- The Workforce/STEM strategy is well thought out and progressing nicely from when it began in 2019. The stakeholder feedback is especially helpful, and it is good to see that the program is attempting to redress the gaps identified in the survey. The reviewer identified some questions and concerns that may or may not be addressed and just not identified in the presentations provided. The education and workforce aspects of the program seem very bifurcated. A lot of educational content is being created, but it is not clear how this connects to opportunities for potential employers and employees other than as a resource. The reviewer urges the program to be mindful of connecting them more and beyond MECC and fellowship opportunities to realize a larger potential workforce interested in powering the blue economy. Perhaps this takes urging NHA to provide dedicated staff and resources to marketing and workforce development as the industry needs to have heavy skin in the game to address retirement and diversity challenges. It is not clear how industry is integrated with DOE and invested in this issue. It is unclear who is presenting and attending the bimonthly dialogue and how outreach is done. MECC and fellowships engage only a limited number of students and potential employees in marine energy. Students can participate in MECC only if their universities and professors are prepared to dive deep into marine energy. There are so many more students who, if exposed to marine energy, would be interested in working in it. There is a big leap between these targeted efforts and the many that the PRIMRE pages purport to engage. It takes another level of effort to engage university career services offices and student clubs (e.g., Society of Women Engineers) to expand who is invited to attend the bimonthly dialogue and exposed to PRIMRE. Many undergraduate majors have the skills to work in marine energy, even if they are not taking the curricula being designed by the program. Students are keenly interested in existing internship and job opportunities, so connecting information to actual paid work is the best way to advertise marine energy's opportunities. Potential employees may visit PRIMRE if a job or internships exists but are unlikely to find or visit PRIMRE by itself. (Note: A Google search for marine energy jobs did not point to PRIMRE. First was the Marine Corps, followed by Indeed.) While it is nice to have a DEI outreach strategy, marine energy is at such an early stage that it is most important to have an inclusive strategy that is not solely focused on women and minorities (unlike hydropower). Be mindful of what educators need at each level. K-12 teachers need to understand the energy system and clean energy's role in that. It is good that marine energy materials are being woven into existing curricula rather than as standalone materials that the program would expect individual teachers to grasp. Community college and university professors have their own needs, which often trump what students/potential employees want/need. Going beyond classroom materials is needed to engage students beyond MECC and the fellowships. It is not clear how much the program is involved in workforce and education efforts at EERE and DOE and with other U.S. government offices. It is good that a DOE federal employee is engaged in the workforce tiger team. This is a worthwhile effort to stay focused on to maximize exposure and opportunities. There are a number of missing ingredients from other EERE (except MECC), DOE, and industry resources. For example, consider connecting with other key U.S. government resources like the U.S. Department of Labor resources such as the Renewable Energy Competency Model. For MECC, consider launching a (private) MECC alumni association on LinkedIn, which is condoned by the U.S. government. (Note: This was done for the Solar Decathlon Alumni Association and blessed by the Office of Management and Budget.)
- Creating the MECC was great, and the development of other competitions is excellent. PRIMRE is an excellent tool to disseminate scientific data over a broad range disciplines. If possible, the reviewer recommends continuing international collaboration and incorporating with DEI and multidisciplinary education.

Project Evaluations

Marine Energy STEM and Workforce Development

NREL

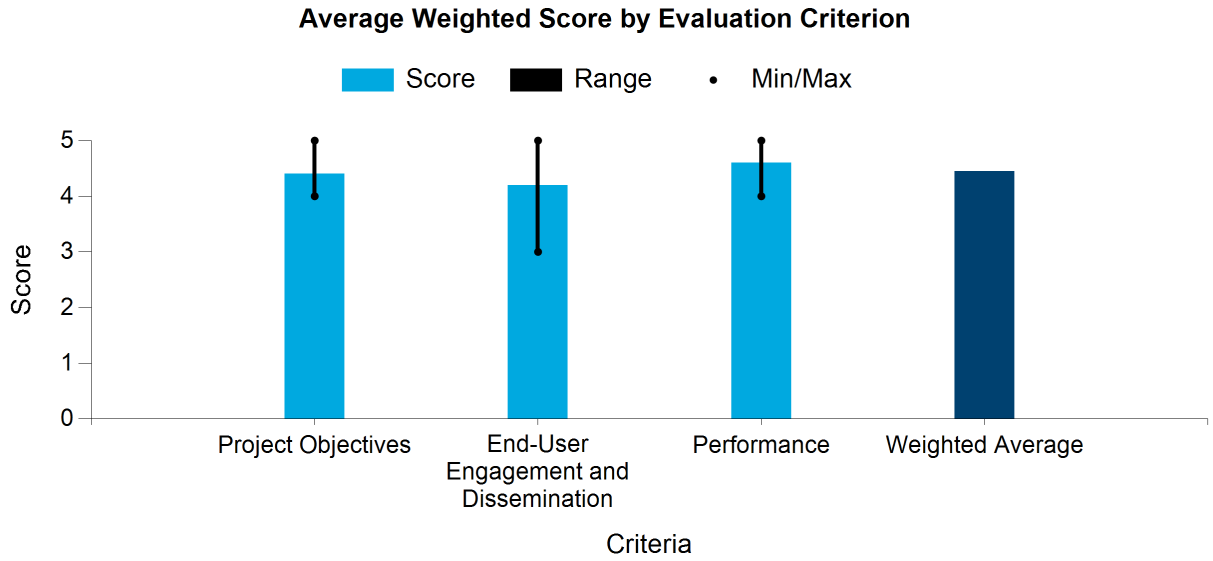
WBS:	2.4.2.405
Presenter(s):	Arielle Cardinal
Project Start Date:	10/01/2018
Planned Project End Date:	09/30/2020

Project Description

Due to the nascent stage of the marine energy industry, there is not currently a steady flow of research, funding, or jobs in this sector, but with growing interest in marine energy, there is an opportunity to grow a new domestic marine energy workforce in the United States.

In partnership with WPTO, NREL has been working to help grow the marine energy workforce of the future by strengthening the STEM workforce pipeline. This work has included deep engagement of the marine energy industry and academia to understand their challenges. The project team has sought student perspectives on the marine energy industry and availability of educational courses, and found strong student interest in marine energy but less awareness of what the industry has to offer and how to pursue a career.

To address these challenges, the project team's work has focused on improving accessibility and distribution of educational materials and increasing awareness of marine energy as a renewable energy career field. These efforts have also served to increase the level of public knowledge on career opportunities in these sectors and help identify typically underserved communities that may benefit from marine energy career pathways. The project team is developing resources to include a publicly available web portal with information on the marine energy workforce, educational materials including curricula and digital applications, research, prizes, competitions, networking, and career building information on the STEM web portal: https://openei.org/wiki/PRIMRE/STEM.



Aggregated Reviewer Comments

- The project matches WPTO Data Access, Analytics, and Workforce Development objectives to support development of new educational resources where gaps currently exist, including curricula and training, to support an evolving marine energy workforce and increase awareness of marine energy opportunities. Including more information regarding marine renewables in school curriculum, especially at a high school level, is an excellent idea to increase awareness of the field as potential career path. It was not clear with whom the material (marine energy workforce opportunities and career paths) is being shared at university levels. Depending on with whom these materials are being shared, there is the risk that they attract people who already had a previous interest in the field rather than increase the number of people interested. It would be useful to share this over multiple disciplines, e.g., business, marketing, marine sciences, computer science, etc., which may be the case, but it is unclear from the presentation. The project has made appropriate progress toward addressing the project objectives with the development of useful material. However, critical go/no go decision points were not addressed in the presentation.
- The Water Power STEM Workforce Development project for marine energy has highlighted a critical gap in the development and implementation of marine renewable energy technologies—the absence of training programs to maintain and expand a skilled labor force to support the marine renewable energy sector. Developing a pipeline for skills that are relevant to the design, installation, and maintenance of marine renewable energy devices, as well as the knowledge and capacity to examine environmental and ecological effects of these devices, are crucial for the future growth of the sector in the United States. This program is taking an innovative three-pronged approach to address this issue and is in line with WPTO's goals of advancing the marine energy sector. There is an absence of curricula focused on marine renewable energies at all levels of primary, secondary, post-secondary and graduate level education, and the work being done through this program will help support growth of the marine renewable energy sector and ensure its success. The program goals are relevant, meaningful, and achievable, and the broad scope of engagement activities (e.g., collegiate competitions, after school programs, Renewable Energy Discovery Island) undertaken to date highlight the success of this work. Given the magnitude of the task ahead, the reviewer believes this program should continue to be supported indefinitely.
- The reviewer noted that the evaluation criteria did not make a lot of sense for this project, so it was difficult assigning scores for a non-R&D project. The three-pronged approach makes a lot of sense and is presented in a good way. The Marine Energy STEM portal contains helpful information and is presented nicely. Conducting a school survey is an excellent first step to figure out the baseline of educational offerings. MECC is an excellent way to expand knowledge of and recruit for the still nascent marine energy industry. The outputs and planned future work are all well thought out and strategic. In particular, working with industry is in the planned calendar and needs to be the center point of this effort. It is not clear how much the educational content being developed is aligned with workforce and education efforts at EERE and DOE and with other U.S. government offices. The reviewer recommended connecting with other key U.S. government resources, like Department of Labor resources such as the Renewable Energy Competency Model. The reviewer noted that this identifies skills needed until reaching water. It is nice to see that the MECC is included in the EERE STEM and Education portal, but it is not clear that effort is made to make sure that effort goes beyond populating the Marine Energy STEM portal. While the Marine Energy STEM portal is nicely done and well laid out, there is nothing mentioned about efforts to work with other EERE renewable energy programs to present a common renewable energy approach to workforce. This is especially important in the K-12 space as effort should be on getting kids interested in renewable energy and providing info about marine and hydropower as part of that as a secondary concern. Educators cannot be expected to be experts on individual renewable energy technologies, especially since it would be enough for them to understand the energy industry and system and how renewable energy fits into that. The program is partnering with excellent organizations (KidWind, the National Energy Education Development Project, and Bonneville Environmental Foundation), and it is good that content is being designed

to weave into existing curricula. Overworked educators cannot be expected to wade through information only specific to water power technologies. The reviewer noted that they attended the Clean Energy Workforce conference that KidWind led. While it is a good conference, it is clear that too many participants represented one technology, which was confusing to educators who should not be advocating for one renewable energy technology over another, and education should concentrate on understanding the energy system and how renewable energy in total fits into that. It is great that a number of meetings will be held with industry players, but there was not enough information to understand what happened in the monthly dialogue series. It would be good to have representation beyond the Hydropower Foundation. There is also not enough information to know if coordination is happening between industry players and undergraduate career services and clubs (such as the Society of Women Engineers) that university students look to for career information and active engagement. The advisory committee charter does not seem to be focused on creating internship and related opportunities for community college and university students. Current students will only become interested in pursuing a career in marine energy if there are work opportunities. The reviewer noted focusing on DEI may not be as necessary for marine as hydropower.

- This is a wonderful program and important for the development of the marine energy sector. The K-12 and broader community outreach is well organized and well considered work. The programs are appropriate, and the wide reach is impressive. The reviewer sees value in having a goal to be deep rather than broad for the university-level work. Supporting undergrad and graduate students to complete a big project in marine energy has a potentially big impact on the wider industry. Helping some universities that have shown or invested in marine energy expertise to build mass capacity of marine energy work in their institutions is very important. The reviewer recommends supporting participation in international competitions, travel funding for conferences and international collaborations, and student organizations that have already been started in the sector.
- Overall, the team seems to be doing an excellent job and is making significant progress. In particular, its efforts appear to be steadily building general awareness of marine energy. Enhancing the number of students with interest in marine energy is a good goal. The team should consider ways to appeal to people's emotions as well people's intellect, as oceans and energy demand equal investment in both domains. The reviewer recommends the team consider requesting further support from WPTO to establish a professional society dedicated to marine energy engineering and science, starting with student chapters in universities and local chapters.

MHK Data Products and User Community Development (PRIMRE)

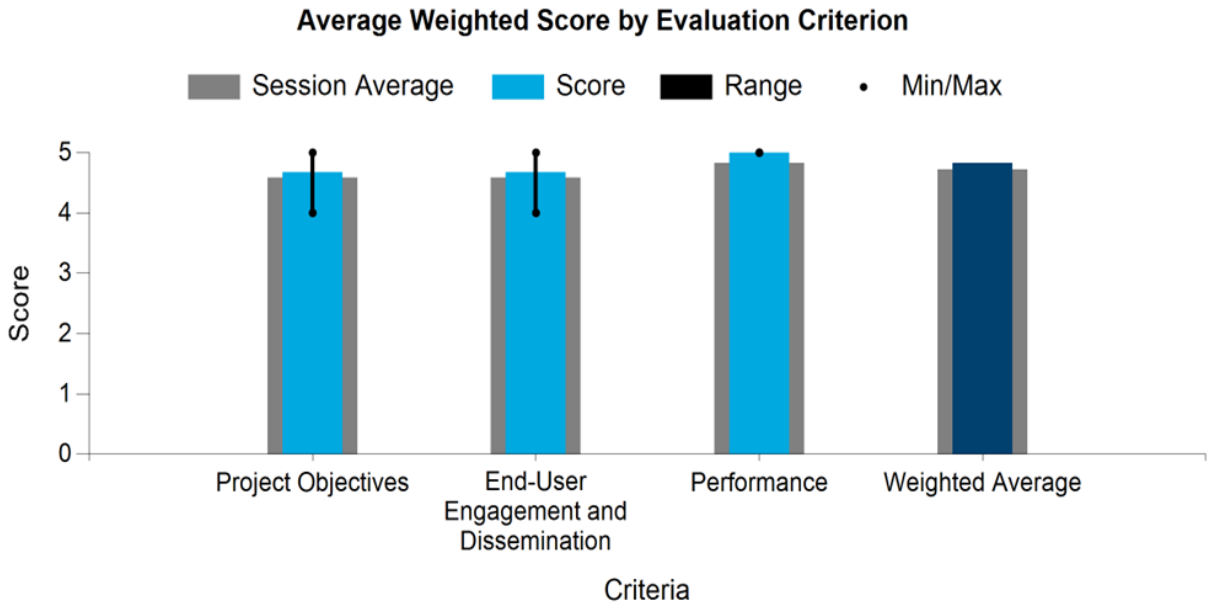
PNNL, NREL, Sandia

WBS:	2.4.1.601
Presenter(s):	Andrea Copping
Project Start Date:	10/01/2016
Planned Project End Date:	09/30/2021

Project Description

PRIMRE is an integrated system that brings together all data and information related to marine renewable energy in the United States with strong international components and links. PRIMRE acts as the portal to seven Knowledge Hubs that each contain a particular type of marine energy data or information.

Information within all seven Knowledge Hubs can be accessed with a one-stop search in PRIMRE and by navigating the individual Knowledge Hubs. PRIMRE allows ready access to some key WPTO-funded projects that are related to one another through an organizational scheme known as Signature Projects and acts as a platform for value-added material that includes lessons learned from the marine energy industry. As an open-access portal, PRIMRE encourages use by all individuals, large and small institutions, and underserved communities. Moreover, PRIMRE is guided by an external Steering Committee and maintains an active outreach and engagement program to bring the marine energy community together on the use of data and information.



Aggregated Reviewer Comments

- The project aggregates and provides access to marine energy data and informational resources. It is a fantastic tool and very impressive. Having all resources centralized in one site makes it easier for anyone interested in the field (e.g., academics, developers, regulators) to access the information. It is well disseminated both nationally and internationally. The reviewer's only comment is that the tool would benefit by having more information regarding international projects (e.g., lessons learned, methodologies used, data publicly available), although the reviewer understands this might be out of the project scope. Future work objectives are clear. Overall, this is an amazing project.

- Compiling and providing access to data and information from myriad WPTO-funded projects for end users (e.g., researchers, developers, and regulators) in a centralized, searchable repository (PRIMRE) is an ambitious project. This team has executed that task masterfully and continues to find ways to integrate additional information into PRIMRE to facilitate the growth of the marine energy sector in the United States. This tool has tremendous inherent value not only for end users in the United States but is directly applicable for the growth of the sector globally. This project plays an important role in WPTO's overall program by providing access to data and information from seven complementary knowledge hubs that are required for the continued growth of the marine energy sector in the United States. Project objectives are reasonable and attainable, and the project timeline is feasible given the excellent progress made to date. The variety of means by which the project team is disseminating information to end users is commendable. The project team should be congratulated on a job well done.
- The future development of outreach and engagement, such as using social media platforms, is excellent! PRIMRE is an exciting tool, and its progress is remarkable. Having an external steering committee is great. If possible, the reviewer recommends including non-WPTO-funded projects in data sources.

International Environmental Data Sharing Initiative (Annex IV Project and Tethys Database)

PNNL

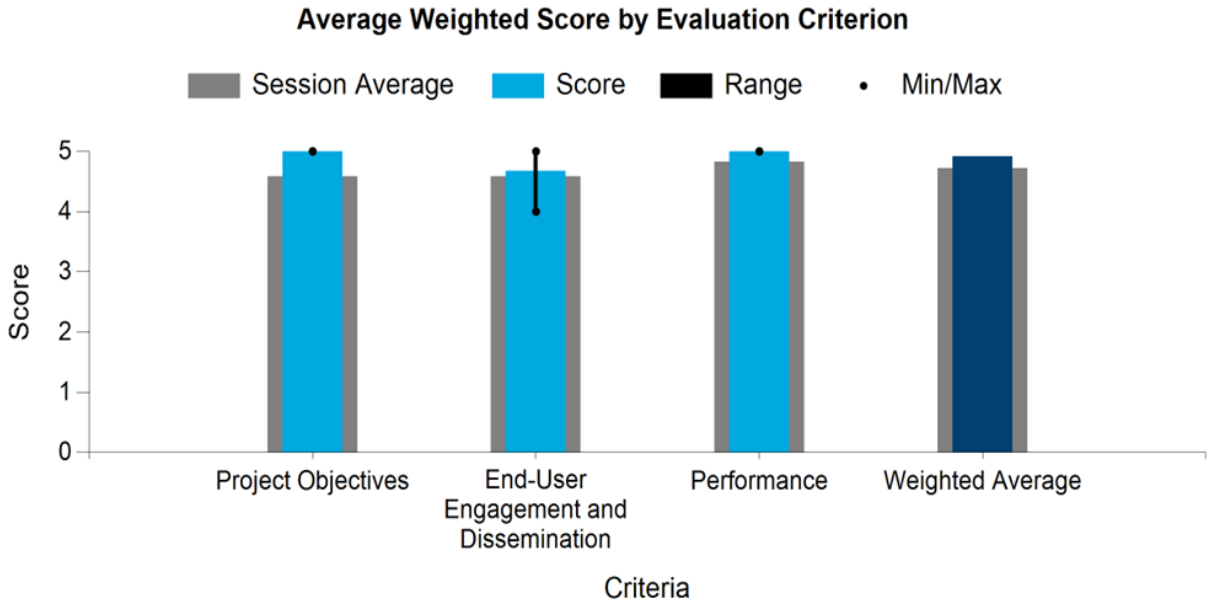
WBS:	2.4.1.602
Presenter(s):	Andrea Copping
Project Start Date:	09/30/2016
Planned Project End Date:	09/30/2021

Project Description

PNNL implements the United States-led OES-Environmental initiative, an IEA OES task supported by 15 other nations, that collects, synthesizes, and disseminates research and monitoring efforts on environmental effects of marine energy. This information, gathered in the Tethys Knowledge Base, helps to reduce the scientific uncertainty that has slowed the development of marine energy projects. OES-Environmental represents the most comprehensive effort to gather data and bring together the marine energy community around potential environmental effects of marine energy development worldwide.

PNNL developed a robust outreach and engagement strategy to bring relevant scientific information to and connect with marine energy audiences in the United States and internationally. Data gaps are examined in cooperation with stakeholders; strategies are developed (e.g., risk retirement pathway and guidance documents); and appropriate studies and monitoring programs are proposed to help fill important data gaps.

The outcomes of this project support the development of reliable and cost-competitive marine energy technologies by providing access to the data and information needed to reduce critical permitting barriers. With greater certainty on the need to collect data that is proportional to the environmental risks from marine energy development, the industry can move forward sustainably.



Aggregated Reviewer Comments

- The project contributes to the Marine Energy Program Activity 4: Data Access, Analytics, and Workforce Development. The Tethys platform provides a global overview of environmental research being conducted, and The State of the Science is a fantastic document (both the full report and the summaries) that can be used by a wide variety of people with different levels of interest. Personally, the reviewer uses Tethys almost daily to keep

up to date with the latest research and finds the knowledge hub intuitive and easy to use. The project has a sound stakeholder and/or end-user engagement strategy with the multiple dissemination paths including email blasts. Overall, this is a fantastic project.

- Uncertainty about the environmental effects of marine energy devices on ecosystems and ecological processes is an important barrier to sector growth in the United States and around the world. The international data-sharing initiative performed under OES-Environmental has done a superb job of identifying multiple stressor-receptor interactions that are of concern, leading the development of State of the Science reports that compile and synthesize the most recent research on those interactions, moving toward "risk retirement" for some stressors, and exploring opportunities for data transferability between jurisdictions to reduce redundancies and facilitate the installation of marine energy devices. The team has done a fantastic job with international engagement since the inception of this project and secured participation from 16 countries. The project objectives are well aligned with WPTO's program goals, and the results to date are tangible and will assist in reducing barriers to testing and facilitating device installations. The development of Tethys provides a searchable repository for information about environmental effects, and the dissemination of relevant information to users via the Tethys blast is an excellent outreach tool. The project has recently expanded its purview to new research topics focused on system-level effects and highlights the progressive thinking that underlies the team's success. This is truly excellent work. To consider in the project going forward, the reviewer notes regulators are not always accepting of the results of environmental effects studies for devices conducted in other regions with respect to their applicability to project permitting in their jurisdiction. While the results of studies may not be transferrable, the methodologies underlying the study likely are, so an effort to compile and make accessible methodological approaches for understanding environmental effects of devices may provide another means to facilitate device testing and project permitting for marine energy devices.
- Engagement with regulators to limit the time to deployment is highly desirable. This team should be commended on the ability to transfer data across different disciplines. Moving forward, the reviewer recommends the team consider identifying the needs and requirements of different types of marine renewable energy.

Grid Value Proposition of MHK

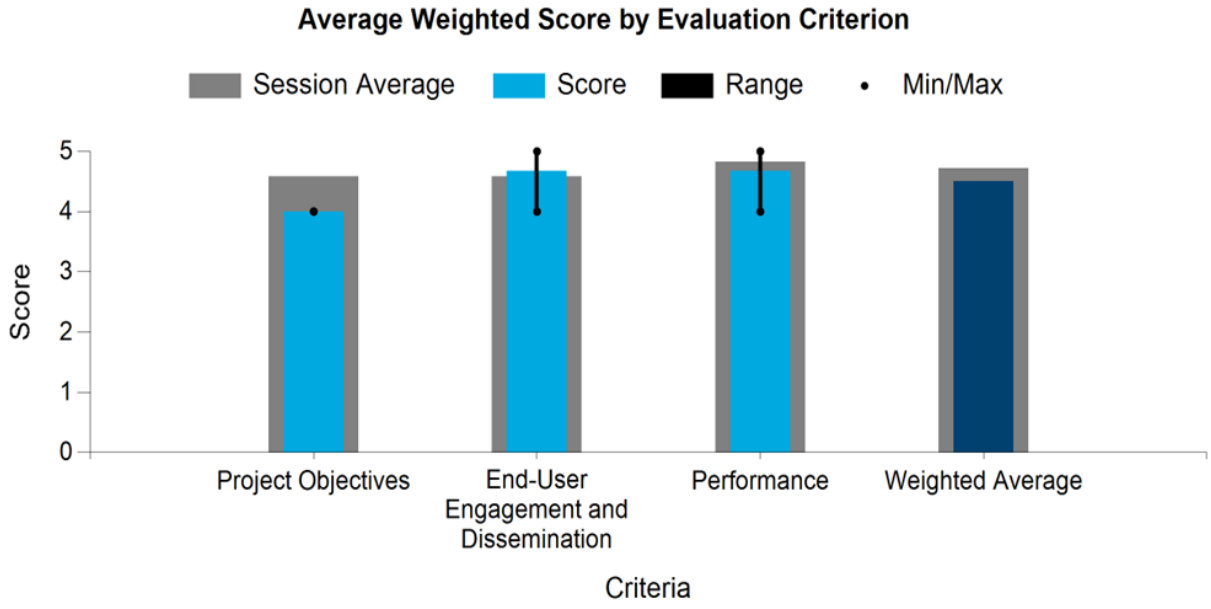
PNNL, NREL

WBS:	2.4.3.603
Presenter(s):	Levi Kilcher; Dhruv Bhatnagar
Project Start Date:	10/01/2018
Planned Project End Date:	09/30/2021

Project Description

A study commissioned by DOE estimated the nation's annual marine energy potential to be approximately 2,300 terawatt-hours per year across the 50 states or more than 57% of U.S. electricity generation in 2019. However, the marine energy industry still faces hurdles to commercialization. While high costs relative to wind energy and solar power remain a key challenge, other hurdles relate to marine energy's value streams not being well characterized and not captured by traditional energy comparison metrics like LCOE. To address this challenge, this project undertakes several types of analyses to identify and illustrate value propositions for marine energy resources. It provides a fresh framework for considering electric system benefits based on unique marine energy attributes and provides analyses illustrating and quantifying those benefits.

Although the technology remains in a development stage, many potential opportunities exist for the deployment of marine energy technologies both in the near term and within typical utility planning timeframes (i.e., up to 20 years). From a resource and technology perspective, marine energy resources can deliver distinct and valuable benefits to different configurations of the grid, whether the bulk system, isolated distribution systems, or remote communities, islands, and microgrids. Marine energy resources can be valuable in increasing technology diversity in a generation portfolio, providing energy where it is otherwise difficult to come by, supporting local resiliency, complementing and being complemented by other resources, and avoiding land constraints.



Aggregated Reviewer Comments

- The project matches WPTO's Data Access, Analytics and Workforce Development objective by providing a method to identify the potential value that marine energy devices present, thus accelerating the understanding of marine energy's value and ensuring marine energy technologies are considered in energy planning. The Grid Value Proposition of Marine Energy: A Preliminary Analysis document is useful and has meaningful applications.

However, it is not clear from the presentation how this method was received by target audiences. It was unclear to the reviewer how likely this is to be adopted in the future. The scope of future work seems appropriate for the completion of the overall objectives of the project; however, go/no-go decision points were not clear.

- This project provides a new way to look at marine energy projects—from a value proposition perspective rather than the more typical (and perhaps myopic) cost perspective. The reviewer finds this project and its approach to be novel and to provide an innovative way to evaluate the contribution of marine energy projects to the power grid at a variety of spatial scales. This is a good project that is in line with overall WPTO objectives. The outputs are meaningful to the continued development and implementation of marine energy devices, and the level of engagement and dissemination of results has similarly been good. This project provides an honest and balanced approach for understanding the value and contribution of marine energy to future energy needs.
- The reviewer enjoyed the use of grid value proposition, and the presentation, as a whole, was enlightening. The assessment of environmental impacts is highly desirable. The reviewer appreciated that the team included an abstract in its submission. Updating wave energy resources for array concepts is needed and highly desired.

Improving the Efficiency and Effectiveness for MHK Permitting: A Toolkit and Engagement for Success

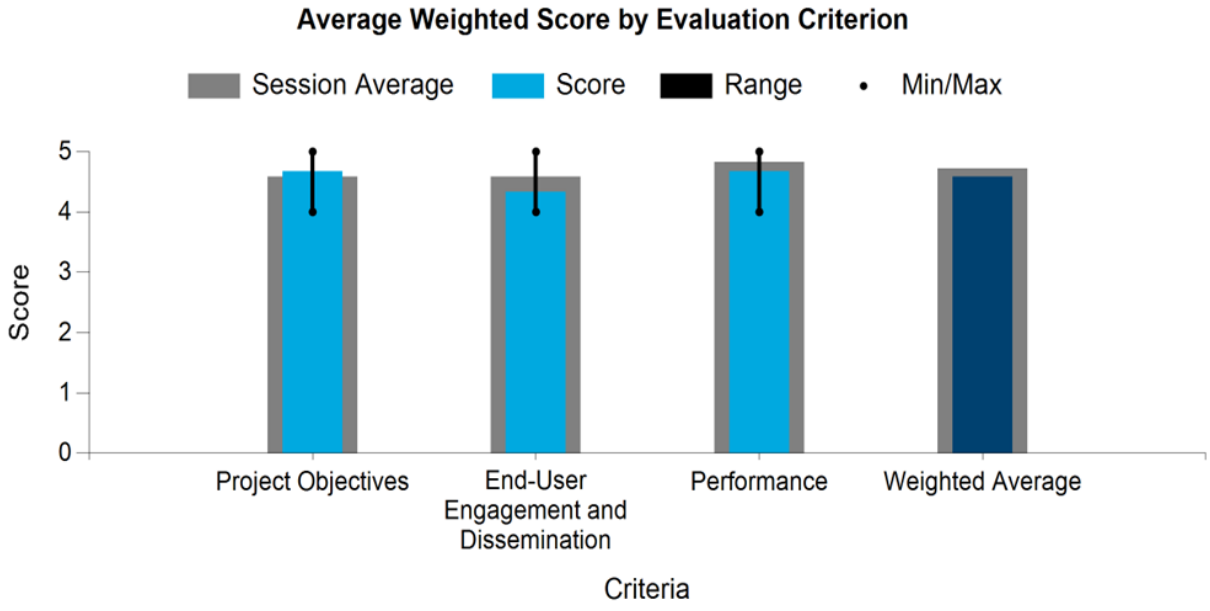
Kearns & West, Inc

WBS:	EE0008634
Presenter(s):	Zach Barr
Project Start Date:	06/01/2019
Planned Project End Date:	12/31/2021

Project Description

The Marine Energy Environmental Toolkit for Permitting and Licensing aims to increase regulators' and developers' understanding of marine energy projects and potential environmental effects to reduce the time and costs required to permit and develop projects. Existing environmental, spatial, regulatory, and scientific data is compiled and distilled into an easy-to-navigate, one-stop-shop webpage organized by technology, stressor, receptors, project phase, consequences, and management measures.

Existing open-source information is used to make the toolkit a transparent and sustainable tool for developers and regulators in the permitting and licensing process. The toolkit is a long-lasting, sustainable solution that can be updated automatically from the existing sources of information. It can also include future applications to address stakeholder needs. The toolkit was developed using a user-centered design with a focus on regulators' needs to gain buy-in for the toolkit's use during the permitting and licensing of a marine energy project.



Aggregated Reviewer Comments

- The project meets the Data Access and Workforce Development activity by aggregating and providing access to marine energy data and informational resources, particularly to reduce cost, time, and uncertainty around the marine energy permitting processes. The toolkit is an amazing tool for developers when applying for permitting by providing a step-wise guide to the regulatory process for different types of marine energy projects as well as timelines from other projects and potential environmental impacts. Early engagement with regulators means the tool meets regulatory needs. Based on the feedback, it seems the tool is a huge success. However, it is not clear at the moment if the tool created is likely to be widely implemented in the future for decision making, but this will likely be clearer after the pilot test. Well done!

- This project advances the marine energy sector by providing a tool for developers and regulators with respect to permitting and accessing environmental effects data. The objectives of the project are well founded and in line with WPTO aspirations, and the approach is reasonable. The project is progressive in that it builds on prior public-sector investment through WPTO, and the expected outputs will be useful as indicated by user testimonials. End-user engagement was employed to assist with the design of the tool, something that was repeatedly highlighted as being important during the program review, so that's particularly encouraging. Outreach and engagement have also been good. Overall project progress and accomplishments are good. This project should assist industry and regulatory agencies with project permitting processes.
- This toolkit is highly useful, and the reviewer is impressed with its development. The reviewer inquired whether the type of people who use the software for workforce development can be measured. This can help broaden the audience and identify and address the needs of new hires. The reviewer was impressed by the vast amount of novel data.