7.0

Education and Outreach around Environmental Effects of Marine Renewable Energy

Author: Deborah J. Rose
Contributors: Mikaela C. Freeman, Curtis J. Anderson, Arielle Cardinal, Betsy Stratton

The marine renewable energy (MRE) industry has faced many challenges in getting projects in the water. In many cases, this is due to long consenting timelines, and occasionally active public opposition, often related to concerns about environmental effects or potential conflicts with other uses of the ocean space. While these concerns are very real, some of them are based on misconceptions or lack of familiarity with MRE devices and how they function (Boudet et al. 2020; Karytsas & Theodoropoulou 2014), or uncertainty or misinformation regarding how MRE devices may affect the environment. These misconceptions are common challenges for other renewable energy sectors or other developments in the ocean (Caporale et al. 2020; Scott 2022; Wiersma & Devine-Wright 2014), though the details of device design, site-specific environmental effects, risk and benefit perceptions, and workforce development may be unique to MRE.

Education and outreach about the potential environmental effects of MRE can help policy makers, regulators, advisors, developers, and the public have a better understanding of the realistic level of risk to focus research efforts associated with new projects and maximize the benefits of MRE to local communities while achieving clean energy goals. Often, this requires innovative and diverse methods of communication (in addition to existing forums) and the translation of technical information to common language for relevant audiences (Brooker et al. 2019; Gunn et al. 2022), as well as tailored strategies for reaching each audience (Smith et al. 2022). Building broad awareness of MRE can spark community interest in projects, or increase social acceptance (MacDougall & Colton 2013; Ramachandran et al. 2020, 2021), similar to other global renewable energy projects (Almulhim 2022; Oluoch et al. 2020; Štreimikienė et al. 2022; Zeng et al. 2022; Zografakis et al. 2010). However, it is important to note that no amount of education can completely alleviate individual concerns, because some of the opposition to MRE is based on individual opinion, local cultural values, or place attachment (de Groot & Bailey 2016; Hooper et al. 2020). Instead, these concerns are best addressed and incorporated into each project design through thoughtful stakeholder engagement and trust-building (see Chapter 5).

Another major challenge for the MRE industry is the development of the workforce across environmental and social science research, business, engineering, and technician roles (Constant et al. 2021; Moran 2021). Relevant workforce and skill shortages have affected many marine industries (Burt 2016; Papathanasiou et al. 2018; Safa et al. 2018), and are compounded by competition with other renewable energies. A large range of expertise is needed to design and deploy MRE devices that successfully meet the economic, environmental, and social goals of a location. Targeted, strategic-level education opportunities for science, technology, engineering, and math (STEM) students from primary school to university level, can help increase awareness and build career pathways for students (Maltese et al. 2014; Miloslavich et al. 2022; Pattison & Ramos Montañez 2022). Of key importance is the support of career pathways for traditionally underrepresented people in marine industries, notably, women and people of color (Behl et al. 2021; Johnson et al. 2016; Mackenzie 2015; Scully 2019; Williamson & Wilson 2019). The development of a diverse and inclusive workforce for MRE will foster creativity, facilitate idea sharing, and enable the equitable growth of the industry (Intemann 2009; Sulik et al. 2022).

This chapter discusses how education and outreach can help advance the MRE industry. Past and current efforts are discussed, including examples of successful strategic efforts to increase awareness of MRE and environmental effects, and support of workforce development necessary for industry advancement. The efforts of Ocean Energy Systems (OES)-Environmental on education and outreach regarding environmental effects of MRE are highlighted within this chapter. Project-level outreach is also discussed to recognize how existing MRE projects can provide education and outreach. Last, future needs that build on past and current work to aid the MRE industry are identified.

7.1. EDUCATION AND OUTREACH EFFORTS FOR MRE

Many education and outreach efforts have been initiated to increase awareness of MRE and environmental effects, gain social acceptance, provide education about a specific MRE project, and support increasing the future workforce.

7.1.1. HOW MRE WORKS

Most people are not familiar with MRE, how it works, how or where it can be used, and the possible benefits of the resource. This can create avenues for misinformation or misconceptions, which can increase potentially unnecessary conflict around proposed projects. An important initial piece of education for MRE is offering clear explanations of what MRE is (and what it is not, as compared to offshore wind technology), and how the different technologies operate. Resources have been produced by numerous organizations about this topic for a variety of audiences and age groups. For example, Mystic Aquarium and the National Renewable Energy Laboratory (United States) collaborated to develop an MRE exhibit; the European Marine Energy Center produced a series of animated informational videos that demonstrate how different types of wave and tidal energy devices operate; and the International Renewable Energy Agency has written several technology briefs on MRE. The physics of various wave, tidal, and

current energy devices are the most clearly described in available materials, while ocean thermal energy conversion and salinity gradient technologies currently have fewer resources available. This aligns with the focus on each of these technologies in terms of available research as well as technology readiness.

It is also important to provide background on when and why the different types of MRE technologies should be used when other renewable energy technologies are available. Discussing how MRE can help achieve renewable energy goals, be more reliable and predictable than other forms of renewable energy, and how it can often be used where other renewable resources are not available will increase the collective understanding of where and how MRE fits in clean energy transitions. For example, MRE can be used for commercial-scale applications to provide power to the grid, for at-sea uses such as ocean observations and offshore aquaculture or can help support coastal resilience in areas where population centers align with available MRE resources.

7.1.2. ENVIRONMENTAL EFFECTS OF MRE

Providing a baseline understanding of MRE technologies—how they work and where they are best applied—helps pave the way to begin discussing how MRE devices and projects may interact with and potentially affect the environment. An understanding of the site- and device-specific environmental effects of MRE is important for regulators and advisors to appropriately consider potential risk when reviewing and approving projects at both small and large scales of deployment. Access to this information is also necessary for individuals concerned about the impacts of devices on their local ecosystems and communities and is tightly linked to perceptions of social and economic effects (see Chapter 4). Being able to identify which environmental interactions are considered low risk, either from information on existing deployments or transferable industries, and can be retired (see Chapter 6) enables research and monitoring to focus efforts on the remaining uncertain interactions. While education itself does not automatically remove barriers to MRE development, and there are many other factors to consider in stakeholder engagement (see Chapter 5), provision of basic information on environmental effects in a variety of formats can help avoid misconceptions and align public perceptions with the current scientific understanding.

Several projects internationally are working on education around the environmental effects of MRE, including the Offshore Renewables Joint Industry Programme (ORJIP), the Triton project at Pacific Northwest National Laboratory, and OES-Environmental. In this section, the efforts of OES-Environmental are emphasized.

OES-Environmental has focused on sharing current research and existing knowledge to regulators, developers, consultants, researchers, and the public using a variety of learning formats. Creating materials tailored for specific groups has made outreach efforts more effective and allowed the information and findings from OES-Environmental to increase broad awareness about the environmental effects of MRE. OES-Environmental's primary audience for outreach and engagement is the existing international MRE community, which includes regulators, advisors, developers, consultants, and researchers. For regulators and advisors, the focus is on moving from scientific information to application in a regulatory context (Figure 7.1; see Chapter 6 for more information). This has included surveys to understand regulatory perspectives and information needs (Freeman et al. 2020; Rose et al. 2023), workshops to present and discuss available information and the current state of the science, and the development of resources to condense and convert research into formats with specific audiences and applications in mind. For example, a brochure was created to provide an overview of environmental effects particularly for regulators who are new to the MRE industry. In addition, guidance documents were created to aid regulators, advisors, developers, and consultants throughout consenting processes. Several tools have also been developed to aid regulators, advisors, developers, and consultants in finding existing environmental data (Monitoring Datasets Discoverability Matrix) and to provide examples of environmental mitigation from various stages of MRE projects (Management Measures Tool). Webinars have been held to share these resources and tools, answer questions, and receive feedback, in addition to traditional publications and conference presentations. Using surveys and open feedback channels as pathways to learn about audiences and how they perceive content provides insight on effective—or ineffective—education and outreach tactics, as well as helps inform future efforts in this area.

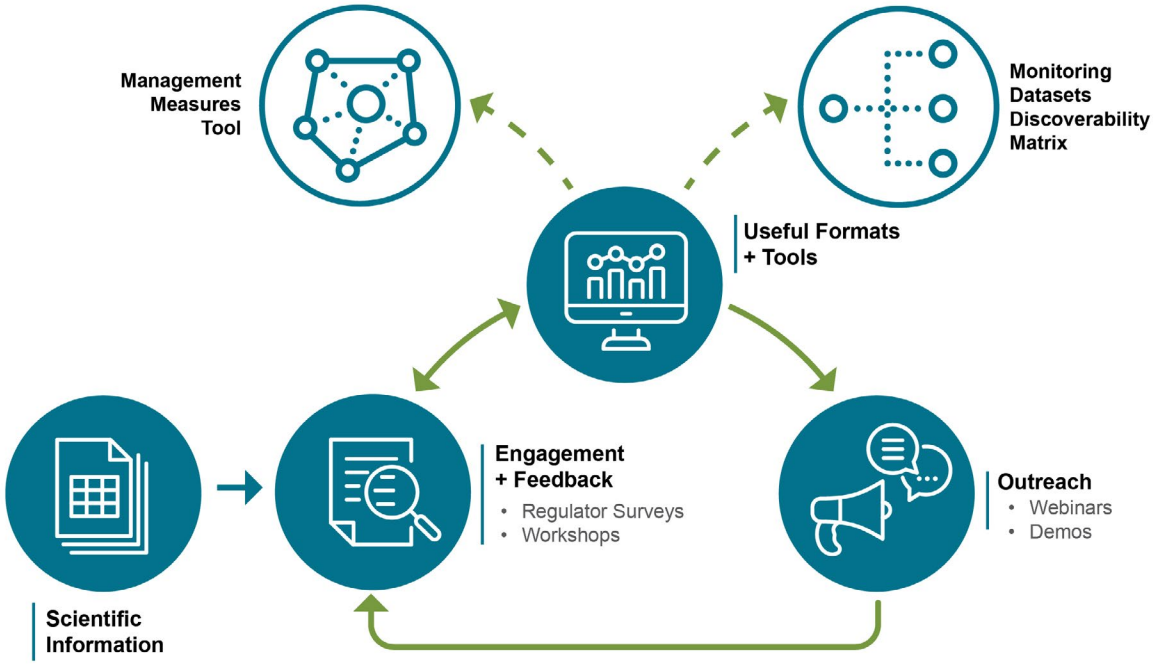


Figure 7.1. Ocean Energy Systems (OES)-Environmental outreach approach for the international marine renewable energy regulatory community—moving from scientific information to application in regulatory processes by creating useful formats and tools for knowledge transfer. See Chapter 6 for additional information on this process. (Illustration by Stephanie King)

OES-Environmental has also explored new formats for sharing scientific information with interested public audiences, including several interview-style podcasts (Figure 7.2) and an article in Sea Technology magazine (Rose et al. 2022). Providing accessible information about the environmental effects of MRE in these formats helps reach new and broader audiences that may not be aware of MRE or environmental effects research, especially because each podcast and magazine has a different but related audience that can be engaged to share information about MRE. Podcasts in particular provide a platform for in-depth, informal 30- to 60-minute conversations about relevant research topics related to MRE that can reach large audiences and can be archived, providing long-term access. This candid approach to sharing research builds trust and transparency and can help reach a wide variety of audiences (Fox et al. 2021), including teachers who have increasingly used podcasts as a tool for lesson enhancement (Gopal et al. 2020). Similarly, magazine articles are transitioning to digital platforms, making the content more sustainable and accessible, and easy to share and link to relevant content channels.

For all audiences, OES-Environmental also uses social media and the Tethys platform to host and promote events and content. Social media enables communication to audiences within the MRE community. However, it can also help reach those outside the research community using nontechnical, nonscientific language in a timely way that can help increase transparency and gain trust from specific audience groups, as well as challenge misconceptions and misinformation (Fox et al. 2021; Huber et al. 2019; Weingart & Guenther 2016). Additionally, social media channels can serve as opportunities to promote research and information about renewable energies (Zobeidi et al. 2022), especially for audiences and communities who might not traditionally have access to scientific information (Dosek 2021; Mueller-Herbst et al. 2020).

Social media handles (@Tethys_Enviro on X, Instagram, and Facebook) are shared between several projects and regularly post about information from OES-Environmental on environmental effects of MRE as well as information from other projects on MRE and wind energy. OES-Environmental also promotes events and content through bi-weekly Tethys Blasts, a newsletter curated for the marine and wind energy communities. Both these social media and newsletters help increase the availability of information for different audiences.

Development of STEM educational material for students and the future MRE workforce around environmental effects is another growing piece of OES-Environmental's outreach work (Freeman et al. 2023). Various types

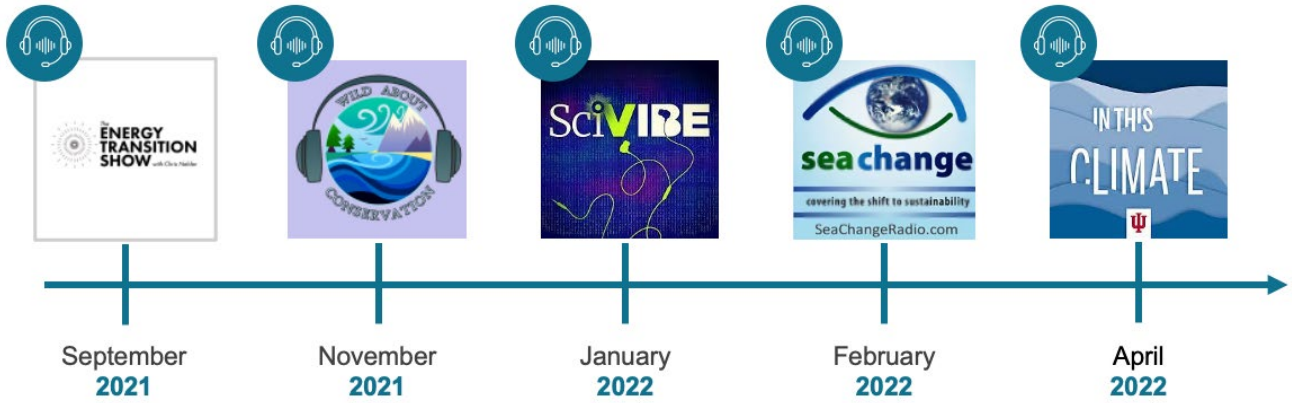


Figure 7.2. Podcast episodes in which Ocean Energy Systems (OES)-Environmental staff have been interviewed. Links to the podcasts can be found on Tethys. (Illustration by Stephanie King)

of content have been developed and are hosted on the Tethys MRE Educational Resources page with STEM students in mind, ranging from primary school to university students (Figure 7.3), though have been found to be useful for other interested audiences as well.

As OES-Environmental continues to synthesize current scientific knowledge about the environmental effects of MRE, strategic outreach and engagement will continue to be a focus to assure important findings are communicated in accessible ways to diverse audiences.

7.1.3. WORKFORCE DEVELOPMENT

To spur innovation and promote growth in MRE, the industry needs to inspire the next generation of MRE workers. There is also growing interest in supporting people working in other energy sectors, the supply chain, or other maritime sectors to transition into the MRE sector. The International Energy Agency (IEA)-OES International Vision for Ocean Energy projected that 300 GW of MRE could be deployed and 680,000 direct jobs could be created globally by 2050 (Huckerby et al. 2016). The MRE industry will need a workforce that mixes strong ocean construction, nautical design, and ocean science with an understanding of advanced materials, innovative power system development, and control theory. Additionally, the industry needs to recruit scientists to perform environmental, social, and economic evaluations of MRE technologies and projects and influence policy to reduce deployment and commercialization barriers. Project support on the business, management, regulatory, legal, and financial side of the industry may also need MRE-specific knowledge. Despite increasing interest in MRE, the beginning stages of the industry present workforce pipeline challenges, including a lack of experience and awareness of potential careers, and competition from other industries for workers.

Efforts to address these needs include more programs and improved program accessibility at all education levels in addition to an increased awareness of MRE as a renewable energy career (Constant et al. 2021).

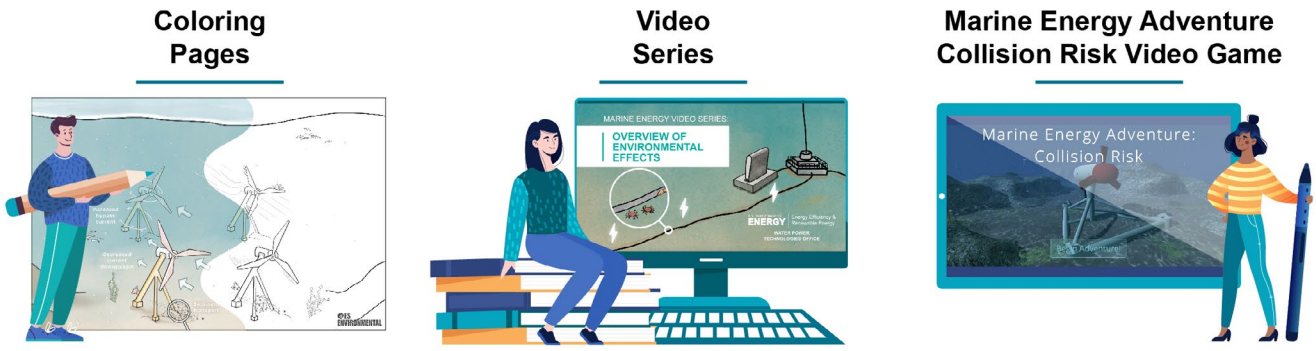


Figure 7.3. Examples of educational content developed or supported by Ocean Energy Systems (OES)-Environmental with science, technology, engineering, and math students in mind. Links to more can be found on Tethys. (Illustration by Stephanie King)

There is much work to be done, but at a minimum, the following must be increased to strengthen the global workforce pipeline:

- Relevant work experiences in MRE or adjacent fields,
- Industry engagement in academia,
- Hands-on learning, and
- MRE-specific coursework for all grade levels.

Many countries have developed workforce training programs or initiatives to navigate some of these challenges and aid in the development of the MRE workforce. Examples of a variety of international workforce development efforts are listed in Section 7.1.5.

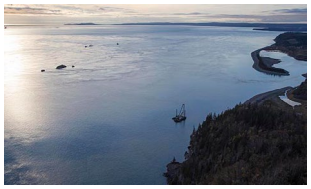
7.1.4. PROJECT-LEVEL OUTREACH

A significant component of MRE project development includes outreach and engagement with stakeholders and others who may be interested in or affected by a new project. While strategic engagement is important to broaden the understanding of MRE, reduce potential concerns or barriers to its deployment, and build the workforce, MRE projects have a unique opportunity to conduct outreach and provide education to local communities and specific stakeholders that may not be reached with general efforts. Stakeholder engagement and participatory planning for MRE are covered in more detail in Chapter 5, though these efforts centered around projects often include information sharing or development of educational content. The combination of project-specific efforts and strategic- or government-level efforts to build public awareness and develop a skilled workforce is needed to advance the industry in particular locations and as a whole (Constant et al. 2021; Freeman 2020).

Several MRE projects or test centers have developed educational outreach materials, as shown in Figure 7.4.

7.1.5. ADDITIONAL EDUCATIONAL OR WORKFORCE TRAINING RESOURCES FOR MRE

The list in Table 7.1 provides examples of resources for MRE that have been developed by many different organizations internationally. While the list is by no means exhaustive, the hope is that by collating and sharing these resources further collaboration can be fostered, and more viewers will be able to access the resources.



Fundy Ocean Research Centre for Energy (FORCE), a tidal energy test site in Canada, operates a visitor center that is free and open to the public both in-person and virtually, and an online learning portal that provides real-time data, an animated tour of the test site, and education information on tidal energy.

European Marine Energy Centre (EMEC), a wave and tidal energy test site in the United Kingdom, developed a Marine Renewable Energy Dive-In Pack, a suite of engaging educational resources for primary school children.

Biscay Marine Energy Platform (BiMEP), a wave and offshore wind energy test site in Spain offers a virtual tour with educational videos of the open water BiMEP site and test installations and the breakwater-integrated Mutriku site.

Pacific Marine Energy Center (PMEC), a marine energy research collaboration with University of Washington, Oregon State University, and University of Alaska Fairbanks in the United States offers a variety of STEM opportunities in higher education, and K-12, such as a wave energy coloring book.

Figure 7.4. Examples of outreach efforts internationally. Fundy Ocean Research Centre for Energy (FORCE); European Marine Energy Centre (EMEC); Biscay Marine Energy Platform (BiMEP); Pacific Marine Energy Center (PMEC). STEM = Science, Technology, Engineering, and Math

Table 7.1. Compilation of educational or workforce training resources for marine renewable energy (MRE). Updated list available on Tethys.

BLUE ECONOMY COOPERATIVE RESEARCH CENTRE	Blue Economy Cooperative Research Centre	The Blue Economy Cooperative Research Centre in Australia is an innovative cross-sectoral research collaboration that hosts an Education and Training Program for researchers to deliver industry-ready PhD graduates.
COME3T	COME3T	Committee of Experts for Offshore Renewable Energies Environmental and Socio-economic Issues (COME3T) is a committee of experts in France that provides scientific knowledge and develops helpful visual information in multiple educational bulletins. COME3T is coordinated by France Énergies Marines.
deftiq	Deftiq Offshore Renewable Energy Courses	Deftiq, in partnership with multiple academic and industry organizations globally, has produced online MRE and offshore wind courses for technology developers, early career researchers, and other workforce development. Multiple courses have been developed, including a course on environmental impact.
FLORES Offshore Renewable Energies partnership in the Pact for Skills	FLORES	Forward Looking at the Offshore Renewables (FLORES) is a large-scale partnership aiming to advance offshore workforce development across the European Union.
FloWave	FloWave	The FloWave Ocean Energy Research Facility offers multiple opportunities for teachers to visit the test facility and participate in competitions.
INTERNATIONAL NETWORK ON INORE OFFSHORE RENEWABLE ENERGY	INORE	The International Network on Offshore Renewable Energy (INORE) is an association of postgraduate students, postdoctoral researchers, and other professionals at early stages of their careers, working in the fields of offshore wind, wave, tidal, salinity gradient, and ocean thermal energy conversion.
integral consulting inc.	Integral Consulting CStories	Integral Consulting developed a MRE chatbot that uses artificial intelligence to answer any question about MRE.
	Marine Energy Collegiate Competition	The U.S. Department of Energy hosts a challenge for interdisciplinary teams of undergraduate and graduate students to advance MRE by exploring opportunities for MRE technologies to benefit other existing maritime industries via real-world concept development experiences.
MARINE ENERGY WALES	Marine Energy Wales School Resources	Marine Energy Wales has developed online education resources that are available in English and Welsh, for primary and secondary school students.
mates www.projectmates.eu	MATES	The Maritime Alliance for fostering the European blue economy through a Marine Technology Skilling Strategy (MATES) project aims to increase ocean literacy with emphasis on offshore renewable energy and shipbuilding, as well as to raise awareness about maritime careers. Eleven pilot experiences in training and skills development have been created and are freely available on the MATES website.
	MRE Brochure	The MRE brochure was developed by Ocean Energy Systems (OES)-Environmental to provide an overview of the environmental effects of MRE development, to familiarize readers with the latest scientific information on the potential impacts of installation and operation of MRE devices in a condensed, visual format.

NEED National Energy Education Development	NEED Project Curriculum	The National Energy Education Development (NEED) curriculum provides comprehensive, objective information and activities for students and educators on the energy sources that can power the United States, including economic and environmental impact information.
Ocean Energy orjip working to accelerate offshore consenting	ORJIP Ocean Energy	Offshore Renewables Joint Industry Programme (ORJIP) Ocean Energy is a United Kingdom-wide collaborative program of environmental research with the aim of reducing consenting risks for wave, tidal and current projects.
Pan-American Ocean Energy Student Network	POES Network	The Pan American Ocean Energy Student (POES) Network, created by the Pan American Marine Energy Conference (PAMEC) Energy Association and Centro Mexicano de Innovación en Energía (CEMIE)-Océano, is a student and early career research-led organization for those in the Americas involved in the MRE sector.
PRIMRE	PRIMRE STEM Page	The U.S. Department of Energy's Portal and Repository for Information on Marine Renewable Energy (PRIMRE) hosts a STEM (sciences, technology, engineering, and mathematics) page to support the workforce development in the MRE industry.
	REDi Island	Renewable Energy Discovery (REDi) Island is an interactive, educational 3D animation of a virtual renewable energy-powered island developed by the National Renewable Energy Laboratory in the United States. that—with help from the next generation of waterpower scientists—could soon become reality.
SAFE WAVE	SafeWAVE Project	The SafeWAVE Project, a multidisciplinary team from Portugal, Spain, France, and Ireland, has developed an education and public engagement framework to enhance ocean literacy, and as part of this work reviewed existing education and public engagement programs.
	Spark Squad comic book	The Spark Squad comic book, developed by the National Renewable Energy Laboratory, follows secondary students as they learn about waterpower technologies, including MRE.
TETHYS ENGINEERING	Tethys Engineering Photo Library	The Tethys Engineering Photo Library hosts photos and illustrations of MRE devices, arrays, and facilities that are available for use. The Photo Library can be a useful resource for showing existing MRE technologies designs to increase awareness and familiarity.
TRITON	Triton Newsletter	The Triton Initiative at Pacific Northwest National Laboratory carries out research and environmental monitoring technologies to reduce barriers to testing, and sharing the information broadly. The Triton newsletter is used to facilitate this information dissemination.
Hydropower AND Marine Energy STEM Workforce Development	Water Power STEM to Workforce	The Water Power STEM to Workforce project focuses on assessing the workforce needs in the United States and supporting the development of educational structures to build the marine pipeline.
WEAMEC MARINE ENERGY	WEAMEC	The West Atlantic Marine Energy Community (WEAMEC) is a consortium of 30 institutions across France that has developed a training roadmap and various initial and continuing training programs for marine energy technical skills.

7.2. FUTURE NEEDS AND CONCLUSION

As the MRE industry continues to progress internationally, education and outreach needs will evolve as well. Consistent education and outreach at both the project- and strategic-levels are essential to increase and maintain public awareness, grow the knowledge base around the environmental effects of MRE technologies, and generate further interest in joining the MRE workforce and supporting project developments. To do this effectively, plans for communicating and disseminating information about MRE should be embedded in the research process to assure education and outreach efforts are accurate, current, and appropriately messaged to keep audiences properly informed. Outreach efforts should be creative, with content developed for specific and diverse audiences (Freeman et al. 2023), and paired with best practices for scientific communication (Gunn et al. 2022) and evaluation of effectiveness (National Academies of Sciences, Engineering, and Medicine 2017; Rodgers et al. 2020). Further workforce development will need to be undertaken with an eye to leveraging resources and lessons learned internationally and from the offshore wind industry, where applicable, as standardization and training programs are developed and connected to more mature marine industry workforce pipelines (Constant et al. 2021).

For OES-Environmental, going beyond scientific publications, reports, and conference presentations enables a further reach with project outcomes, allows for crafting messages for specific audiences in an evolving public space, and employs a range of techniques and formats to deliver similar messages to evaluate and increase effectiveness. In future work, continued and improved collaboration and cross-promotion of materials with like-minded initiatives and organizations internationally is recommended to develop synergies and better leverage existing networks and content.

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