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Case study on the novel permitting and authorization of PacWave South, a US grid-connected wave energy test facility: Development, challenges, and insights

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ABSTRACT

Marine energy (i.e., energy from waves, tides, currents) in the United States is a nascent industry. In particular, permitting processes—an uncertainty for industry advancement that can be costly and time consuming to navigate—have rarely been tested and used for marine energy. The novelty of the marine energy industry and utilization of open ocean permitting processes that were not originally developed for marine energy have led to extensive efforts to gain consensus amongst state and federal regulatory agencies to authorize marine energy projects. In 2021, Oregon State University successfully completed permitting of a wave energy test facility, called PacWave South, off the coast of Oregon, which is designed to advance wave energy research and development. This article documents the multi-year process that Oregon State University used to receive federal and state authorization for a pre-permitted commercial-scale grid-connected facility by detailing the development of the test facility, management of uncertainty and challenges, and key decisions. The PacWave South case study provides insights for the larger marine energy community as the industry advances towards commercialization.

1. Introduction

Marine energy (ME) (e.g., wave, tidal, ocean current) is a novel industry using innovative technologies to generate electricity, but commercial-scale ME has yet to be developed. To advance this clean energy resource, testing infrastructure has become a primary focus for enabling technologies to reach commercial maturity (Lehmann et al., 2017). In the development pathway from simulated device performance to small-scale versions in test tanks and modest-scale devices that are robust enough to be deployed in marine waters, the final great leap is testing at the commercial-scale in the open-water marine environment (Aderinto and Li, 2018). Given the extensive permitting requirements for ME projects, individual developers are challenged to effectively test scaled-up devices for their environmental, energy, and mechanical/-electrical performance (Patrizi et al., 2019; Jiang et al., 2020). A solution to this suite of problems has been the development of test facilities, which have facilitated deployment of devices around the world by providing infrastructure (such as grid connections and supply chains) and research expertise to developers, as well as help navigating permitting requirements.

Currently, the United States (US) industry has no domestic facility in which to test and verify reliable operations and electric generation of commercial-scale ME devices[1]; this would require an open-water grid-connected facility with individual, dedicated test berths. PacWave South, a recently authorized test facility, to be constructed 7 nautical miles (NM) off the central coast of Newport, Oregon, aims to fill this critical gap, specifically for wave energy (Pacific Energy Ventures, 2011). The project proponent, Oregon State University (OSU), will provide a pre-permitted, grid-connected facility to deploy full-scale wave energy at four dedicated test berths (Fig. 1). In this case, pre-permitted means that each individual developer will not need to acquire additional permits to deploy devices, but instead are included

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[1] The US Navy's Wave Energy Test Site is the US's first grid-connected test site of its kind but focuses on supporting testing of pre-commercial wave energy devices (see Box 1).

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under the PacWave South authorizations. These berths will offer device developers the ability to measure the electrical, mechanical, and environmental performance of their devices (Federal Energy Regulatory Commission, 2020).

In 2011, OSU initiated the permitting process to develop this first-of-its-kind facility in the US. Originally called the South Energy Test Site, in 2018 the facility was officially renamed PacWave South. The pathway to receive authorization for the full scope of PacWave South presented a considerable challenge because few ME projects have been licensed in the US and only two have received commercial authorization (O'Neil et al., 2019).

It should be noted that PacWave also includes a 1 NM^2 site, originally called the North Energy Test Site but renamed to PacWave North, located 1.7 NM from shore at depths ranging from 45 to 55 m. PacWave North lies 9 NM north of PacWave South and is a non-grid-connected site for testing prototype and small-scale pre-commercial wave devices, as well as technologies designed for non-grid applications. PacWave North required an authorizing permit and a seafloor lease from the Oregon Department of State Lands (Oregon State University, 2020). Though individual permits are needed for each deployment at PacWave North, the site offers a permitting process of likely less than one year given the scope and duration of non-grid tests. Since 2012, one wave energy device has been tested at this site, and an instrumentation buoy has been deployed twice for monitoring purposes (Oregon State University, 2020).

This article specifically focuses on PacWave South (hereafter referred to as PacWave), and the challenges and lessons learned in navigating the US ME regulatory regime. An overview of the US ME regulatory context and PacWave's permitting process are provided. Strategic decisions to secure local, state, and federal authorizations to construct and operate PacWave are reviewed to highlight insights gained from the permitting process. While PacWave is a unique facility in the US, the lessons learned will benefit future efforts to authorize ME deployments, for both testing and commercial developments. This article is intended to aid the ME industry as it advances to commercial stages and to offer insights into the regulatory process for clean energy innovation in the US.

2. Background

2.1. Regulatory context for ME

In the US, regulatory processes for ME projects involve several federal and state agencies and authorities. The Federal Energy Regulatory Commission (FERC) has jurisdiction for licensing all water-powered ME projects that are grid-connected in state waters (from shore out to 3 NM) and the US Outer Continental Shelf (seaward of state waters to 200 NM) (18 CFR §§ 4; Bureau of Ocean Energy Management and Federal Energy Regulatory Commission, 2020; Federal Power Act of 1920; National Oceanic and Atmospheric Administration), although the licensing processes are designed for traditional hydropower facilities with minimal adaptation for ME. Three types of processes are available: Traditional, Alternative, or Integrated Licensing Processes (O'Neil et al., 2019). In 2005, the Integrated Licensing Process (ILP) became FERC's default process for all applications; therefore a project proponent is presumed to use the ILP unless they obtain FERC approval to follow the Traditional Licensing Process (TLP) or Alternative Licensing Process (ALP) (Bureau of Ocean Energy Management and Federal Energy Regulatory Commission, 2020; Department of Energy, 2020). To begin the FERC licensing process, a Notice of Intent and Pre-Application Document (PAD) are filed along with the request to use the TLP or ALP, if desired. Because obtaining a FERC license can be complex, settlement agreements have been used as a means of conflict resolution for elaborate negotiations because they aid in resolving disputes and identifying solutions such as adaptive management (Levine et al., 2018).

In addition, seafloor leases are required and vary by federal (from 3 to 200 NM) or state jurisdiction. For projects located on the US Outer Continental Shelf, the Bureau of Ocean Energy Management (BOEM) has jurisdiction for seabed and research leases (Bureau of Ocean Energy Management and Federal Energy Regulatory Commission, 2020; 30 CFR §§ 585). Similar to FERC's PAD, BOEM requires a Site Assessment Plan (SAP), unless a waiver is requested and granted on a case-by-case basis as was the case for PacWave. PacWave utilized the FERC PAD to provide BOEM the necessary information typically found in a SAP, which allowed for a waiver being granted. For ME projects that are grid-connected in federal waters, both a FERC license and a BOEM lease must be secured in order to move forward with a project (O'Neil et al., 2019). To clarify jurisdiction for renewable energy projects, in 2009 the US Department of the Interior and FERC signed a Memorandum of Understanding that helps streamline this BOEM[2]-FERC joint process, details the need to secure a BOEM lease before FERC will issue their license, and stipulates that FERC will lead the National Environmental Policy Act (NEPA) review (18 CFR §§ 4; Department of Interior and FERC, 2009). Because wave and ocean current energy devices are the most likely technologies to be located in federal waters, this joint process will be most applicable to these types of ME developments. Alternatively, tidal energy devices, and some wave energy devices, could be located in state waters where seafloor leases are issued by the responsible state agency.

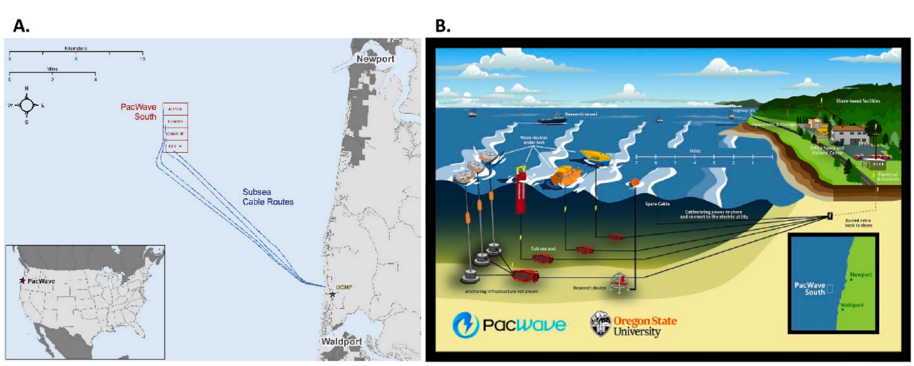

Fig. 1. A. Map of PacWave South off the coast of Newport, Oregon, United States. PacWave South is located 7 NM offshore and provides four test berths located in depths ranging from 65 to 78 m. B. Detailed overview of the different offshore components of PacWave South, including a depiction of deployments at the four test berths.

[2] BOEM is an agency within the US Department of the Interior. The Minerals Management Service (MMS) was responsible for seabed leases until MMS was incorporated as part of BOEM in 2010. MMS is therefore mentioned in the 2009 Memorandum of Understanding, but jurisdiction now lies with BOEM.

Other federal agencies have jurisdiction in the marine environment that may apply to ME projects, such as the US Coast Guard (USCG) for navigation; the US Army Corps of Engineers (USACE) for dredging and filling (Section 404 nationwide permit); the National Oceanic and Atmospheric Administration (NOAA) Fisheries for consultations on essential fish habitat, endangered species (e.g., certain fish, marine mammals, and sea turtles) and marine mammals; and US Fish and Wildlife Service (FWS) for consultations on migratory birds and endangered species under their jurisdiction (e.g., birds) (33 CFR Subchapter C.; 50 CFR §§ 222; 50 CFR §§ 18; 50 CFR Subchapter II).

State agencies have jurisdiction for projects beyond the seafloor lease described above if a project uses state land or shorelines, interacts with state-protected or managed natural resources or user communities, or triggers federal consistency requirements. For instance, pursuant to the Coastal Zone Management Act, state agencies may review permits for federal actions that may affect coastal resources to ensure they are consistent with a state's approved Coastal Zone Management Plan (Department of Energy, 2020; Coastal Zone Management Act of 1972). For a comprehensive review of US regulations relevant for ME, see the *Handbook for Marine Hydrokinetic Regulatory Processes* (Department of Energy, 2020).

2.2. History of permitting ME in the US

In the US, only a few projects have received final authorization for commercial-scale ME activities (O'Neil et al., 2019) (Box 1). The most proximate example regarding operations and installation is the Hawaii-based Wave Energy Test Site (Box 1), but differs as it is entirely under US Navy jurisdiction rather than under FERC jurisdiction. Because of this and the location of PacWave in federal waters, permitting of PacWave is the first application of the joint BOEM-FERC regulatory process for ME.

Other non-commercial-scale ME projects have taken alternative routes to authorization. Four tidal energy projects pursued the FERC pilot project license process for testing devices: the Roosevelt Island Tidal Energy (RITE) project by Verdant Power (New York), both the Cobscook Bay project (Maine) and the Igiugig project (Alaska) by Ocean Renewable Power Company, and the Admiralty Inlet project by Snohomish Public Utilities District (Washington). Pilot licenses were issued for both Ocean Renewable Power Company projects and for Admiralty Inlet, whereas RITE was exempted (known as the Verdant exemption) because the devices were to be deployed for demonstration purposes only (O'Neil et al., 2019). However, none of these projects have handled the degree of uncertainty in the operating environment and installation, the associated complexity of deployment, or the full suite of modern regulations that PacWave encountered.

3. PacWave South case study

3.1. Development of PacWave

In 2011, the US ME industry published a roadmap, stating that construction of testing facilities for prototype and commercial-scale devices was essential for successful industry commercialization (Ocean

Box 1
Full-scale US marine energy developments that have received federal authorizations to date.

Wave Energy Test Site.

The first grid-connected wave energy test site in the US is located at Kaneohe Marine Corps Base Hawaii, off the coast of Oahu, Hawaii. The site, known as the Wave Energy Test Site (WETS), was developed by the US Navy to assess the potential use of wave energy as power for the US Navy and is operated by the Naval Facilities Engineering Systems Command (NAVFAC) (Cross et al., 2015). The site includes three berths that are permitted for the testing of pre-commercial wave energy devices, specifically point absorbers and oscillating water column devices. The Hawaii National Marine Renewable Energy Center works with the US Navy to help assess and monitor deployed devices.

The permitting process for WETS differed from a typical marine energy development because the power is delivered to the US Department of Defense and therefore neither a Federal Energy Regulatory Commission (FERC) license nor state approvals were needed (Ram et al., 2004). For the permitting of the original 30 m depth test berth in the early 2000s, a National Environmental Policy Act authorization from the US Department of Energy and an environmental assessment from the US Navy, neither of which found any significant impacts, were required. Overall, the process was minimal in terms of the required time and procedures because of the location on military lands and the initial permitting process was completed in two years. A later expansion was permitted in less than a year (Hawaii National Marine Renewabl e Energy Center et al., 2011). The environmental assessment for permitting two additional berths at 60 m and 80 m depths concluded after nearly three years in 2014. Permitting for device deployments at WETS requires a US Navy environmental review, performed by NAVFAC Pacific and the NAVFAC Engineering and Expeditionary Warfare Center, in consultation with National Oceanic Atmospheric Administration and a US Army Corps of Engineers permit.

Finavera Renewables Makah Bay Project.

Finavera Renewables, previously AquaEnergy Group, proposed to develop a wave energy project off the coast of Makah Bay in Washington State. The plan was to deploy four 250 kW wave devices. Finavera Renewables received a Preliminary Permit from FERC in 2006, which gives priority for licensing at the location, and pursued FERC's Alternative Licensing Process. In 2007, they received a five-year "conditioned" license from FERC. A "conditioned" license requires the licensee to seek and independently comply with other agency permits and does not allow for construction or installation activities until supporting permits or actions are complete (e.g., federal consistency or state water quality certificate) (Federal Energy Regulatory Commission, 2007). While this was the first wave energy project to receive any FERC license, the company surrendered the license in 2009 due to capital restrictions and economic conditions that were not favorable (O'Neil et al., 2019).

Reedsport Ocean Power Technologies Wave Park.

Ocean Power Technologies (OPT) received a FERC license to develop a wave energy project, Reedsport OPT Wave Park, off the coast of Reedsport, Oregon. The initial plan was to deploy up to 10 devices with an installed capacity of 1.5 MW. OPT received a Preliminary Permit from FERC in 2007 and began to pursue FERC's Traditional Licensing Process that same year. In 2010, OPT, regulatory agencies, and stakeholders entered into a settlement agreement to resolve issues in order to receive a FERC license (Ocean Power Technologies, 2010). This included consensus on the use of an adaptive management approach to address unanticipated effects over the life of the project (Ocean Power Technologies, 2010). The full-scale commercial license to operate was issued by FERC in 2012—the first in the US. However, in 2014 OPT surrendered the license due to the high costs of the project and inability to secure funding (O'Neil et al., 2019).

Renewable Energy Coalition, 2011). The same year, OSU began the planning process for PacWave with a feasibility study (Fig. 2). The vision for PacWave was to "leverage [OSU] expertise and industry partnerships to develop a full-scale, grid-connected ocean energy demonstration center that can accommodate multiple devices of various technology types and scales" (Pacific Energy Ventures, 2011). Ten years later, the process to permit PacWave as the US's first open-water pre-permitted commercial-scale test facility concluded with the procurement of a BOEM research lease and FERC license in 2021 (Fig. 2).

3.1.1. Site selection

The primary function of the initial feasibility study was to support decision-making for site selection as this was a significant decision that necessitated public engagement and feedback (Pacific Energy Ventures, 2011). The study detailed the identification of ideal site characteristics and a technical evaluation of potential sites in Oregon based on a set of criteria. Oregon is well suited for ME as there is a strong annual wave resource, the state has aggressive laws requiring utilities to deliver renewable energy, and coastal ports and nearby industrial centers offer proximity to the marine supply chain and supporting businesses (Pacific Energy Ventures, 2011; Aquatera Ltd, 2014).

OSU engaged with industry, regulators, and other stakeholders to understand technical needs, regulatory needs, and interests for development. Based on this input, criteria were developed for an initial selection of four candidate sites, as well as a down-selection to two locations and decision about the final location (Table 1).

The four initial sites were Warrenton on the north coast, Coos Bay on the south coast, and Newport and Reedsport both on the central coast. While all four locations met the technical requirements, Newport and Reedsport, located about 70 miles apart, were chosen as the two final sites. Newport offers a deep-water port and the advantage of OSU's Hatfield Marine Science Center and other marine science facilities based in the community, as well as good stakeholder representation, especially the fishing community through Fishermen Involved in Natural Energy (FINE). However, Newport's public utility, Central Lincoln Public Utility District, did not have a strong incentive for direct renewable energy project development. Alternatively, Reedsport is moderately close to a deep-water port and close to a bay for maintenance, and it has access to electric transmission onboarding, reduced infrastructure costs due to deep-water near the shore, and the potential to leverage environmental analyses from the previous Reedsport Ocean Power Technologies Wave Park project that was fully permitted (Box 1) and slated to be developed nearby.

Community Site Selection teams for Newport and Reedsport were assembled and comprised stakeholders and community members such as commercial and recreational fishers; tribal representatives; utilities; county, city, and port representatives; other ocean users; and members of the public (PacWave, 2020). The teams submitted proposals at the end of 2012 to OSU for consideration. In January 2013, OSU selected Newport because it provided the right balance of access to deep-water ports and associated industries, bathymetry and depth, shoreside infrastructure, community support, access for developers, minimal effects on other ocean users, and proximity to OSU's Hatfield Marine Sciences Center (Pacific Energy Ventures, 2011).

Table 1
Criteria used to select the four candidate locations and additional criteria used to down-select to two locations and ultimately choose the final location (Pacific Energy Ventures, 2011; Oregon State University, 2013a).

	Parameter	Criteria
Site criteria to select four initial locations	Water depth	60–100 m
	Proximity to necessary facilities	Within 50 NM of the nearest deep-water port, within 15 NM of the nearest service port
	Shore landing	Within 5 miles of 115 kV transmission line
	Habitat	Soft bottom
	Leverages existing industry activity	Presence of industry/supply chain
Additional criteria used for both the down-selection and choosing the final PacWave location	Convenience and proximity for personnel	Ability to access location via plane or car
	Energy resource intensity	Adequate wave resource
	Access to utility infrastructure for energy take-off	Proximity to interconnection
	Potential effects on human uses and the environment	Minimal or low risk
	Regulatory	Understanding of required permits and authorizations
	Cost	Cost estimates to compare sites
	Baseline studies	Existing information available
	Long-term environmental monitoring	Existing information available

After selecting Newport as the base of operations for PacWave, focus turned to selecting the specific offshore area. A 6 NM^2 location was first recommended by FINE, based on a set of criteria for suitable areas (Oregon State University, 2013b). OSU collected additional data to characterize the habitat use of important species and populations and assessed the ambient signatures of electromagnetic fields and underwater noise (Oregon State University, 2013a). From these data, a 2 NM^2 portion of the original area was chosen as the final location for PacWave (Fig. 1). The selection of this location which was first proposed by FINE was particularly important in gaining local support for permitting the test facility.

Funding

Federal funding from the US Department of Energy (DOE) Water Power Technologies Office has been critical to PacWave's development. DOE, seeking to develop and fund a deep-water, high energy, open-

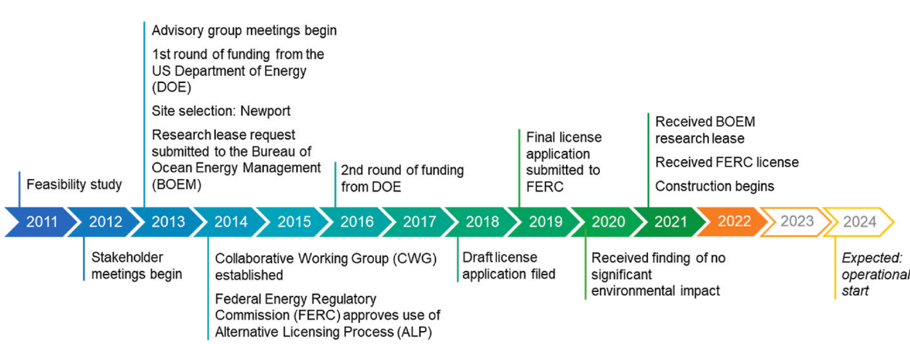

Fig. 2. Timeline of the development and permitting process for PacWave, including construction and expected operational start.

ocean grid-connected test facility, provided an initial $4 million funding installment for PacWave (Oregon State University, 2013c), and an additional $35 million in 2016 for OSU to develop and operate PacWave. Both installments were awarded to OSU after being selected through DOE's competitive funding opportunity process. An additional $26 million was appropriated from the US Congress to DOE to support long-lead procurement activities for PacWave. Additional funds have also been received from the State of Oregon and several other entities (PacWave, 2020).

The nature of the main funding source for PacWave—DOE competitive funding opportunity announcements—affected the project timeline and trajectory. Unlike private or public funds that are allocated directly to agencies for large infrastructure projects (such as those completed by federal and state departments of transportation), competitively awarded public funds create gaps in funding and an additional layer of uncertainty. Such processes require significant administrative procedures, invite competitors for the same work, and have timelines that may be mismatched with those for project development. This process also follows rigorous guidelines and typically requires applicants to offer extensive matching funds. In addition, it is challenging to forecast costs with high degrees of precision, as required in competitive grant solicitations, for never-before-built infrastructure in the US. Relying on this source in this staged fashion resulted in timing and budgetary uncertainty for OSU, an additional dimension of process complexity. One of the reasons that OSU selected FERC's ALP was to accommodate the potential for delays in the process due to funding with the ALP's flexible timeline (see Section 3.1.3 and Section 4.1.1).

3.1.2. Implementation

Throughout the development and implementation of PacWave, OSU engaged stakeholders on decisions made throughout the process in order to recruit support and greater momentum for authorization of PacWave. Stakeholder meetings began in 2012 on an informal basis in order to coordinate with relevant state and federal agencies, share information, and discuss initial plans (Fig. 2). In early 2013, an advisory group was formed to help navigate project development and to identify regulatory and environmental concerns and considerations. This advisory group included representatives of BOEM, DOE, FERC, FWS, NOAA Fisheries, Oregon Department of Fish and Wildlife (ODFW), Surfrider Foundation, USACE, and USCG, among others.

Based on discussions with the advisory group and support from resource agencies, OSU elected to pursue FERC'S ALP. The ALP is notable for its flexibility in timeline and its design to accommodate settlement, or similar, agreements among parties to the license. The flexible timeline helped manage the intermittent nature of DOE funding, which was uneven due to federal budgets and competitive application cycles. The ALP also supports inclusion of FERC staff in the pre-application phase and allows an applicant-prepared environmental assessment. OSU requested approval to use the ALP by filing a Notice of Intent PAD in April 2014 and received FERC approval in May 2014 (Oregon State University, 2014). During this time, OSU also submitted a renewable energy research lease application to BOEM in June 2013 in order to conduct site-specific surveys on the physical and biological conditions.

Pursuant to ALP requirements, the advisory group was formalized in 2014 as the Collaborative Workgroup (CWG). The CWG included federal agencies (such as BOEM, NOAA, USACE, and the US Environmental Protection Agency), state agencies (such as ODFW, Oregon Department of Environmental Quality, Oregon Department of Land Conservation and Development, and Oregon Department of State Lands), tribes (the Confederated Tribes of Grand Ronde and the Confederated Tribes of Siletz Indians), and local entities (such as Lincoln County, the City and Port of Newport, Oregon Wave Energy Trust, and Surfrider Foundation) (Oregon State University, 2014; PacWave, 2019). A FERC representative also served on the CWG to advise on FERC licensing requirements (PacWave, 2019).

With FERC as the lead agency and BOEM, DOE, and USACE as cooperating agencies, the end goal was to receive a FERC license and an accompanying BOEM lease for a duration of 25 years (Oregon State University, 2013a). In addition, other permits and authorizations were needed such as a USACE permit, a USCG private aid to navigation approval, and compliance with federal consistency requirements regarding impacts on state resources (Table S1 in Supplementary Materials) (Oregon State University, 2013a; Federal Energy Regulatory Commission, 2021).

3.2. Managing uncertainty and complexity

PacWave is a unique development that has navigated an intricate authorization process. The March 2021 federal license is a significant achievement in light of the complexity and uncertainty that had to be managed by OSU, the CWG, and the authorizing agencies.

3.2.1. Defining the project

For OSU, process initiation began with outreach and engagement with coastal communities. Relevant agencies were also brought in early to the design process, through the advisory group and CWG, to facilitate discussion, provide feedback on potential design considerations, and share thoughts about how best to mitigate potential concerns. There are advantages and disadvantages to engaging stakeholders and agencies while the design of a project is still under development. In its favor, it allowed for design elements that directly conflict with existing users and standard practices or other requirements to be identified up front. Disadvantages include setting expectations for a parameter that may change, perhaps multiple times, and explaining such updates about the project features and operations. Moreover, by not having details specified in advance, stakeholders may feel less confident or not able to engage fully in the process due to uncertainty and unknowns. In the end, designing PacWave with stakeholder input proved helpful to the overall success of permitting the test facility.

From the outset, OSU defined the general confines of the test facility, such as specific technical parameters (e.g., wave energy devices, cables, etc.). The spatial envelope of the facility was first assessed with an initial 6 NM^2 area, which was further refined to the 2 NM^2 final site. Through community and stakeholder engagement efforts, both of these areas were chosen with input from FINE representing marine users, port commissioners representing maritime commerce, and other stakeholders to minimize effects on ocean users (Oregon State University, 2013a, 2013b). Notably, the FINE representatives were in favor of the area chosen and were "willing to give up good fishing assets because [they are] staunchly for natural energy research" (Oregon State University, 2013b).

Due to the range of potential devices, extensive discussion took place within the CWG regarding authorization—discussing permitting for the entire facility and all operations versus having incremental authorization as developers sought to deploy devices at PacWave, with many potential permutations. Resource agencies expressed concern about analyzing the range of potential impacts and suggested that each device would need to have its own environmental assessment. This would have allowed for more precise review, but would also have created challenges and barriers to individual device deployment once PacWave was operational, affecting the timing of authorization, certainty of operations, and value of PacWave to the industry. OSU instead sought a path whereby agencies could authorize the entire facility and subsequent deployments, therefore "pre-permitting" potential devices in advance to meet the overall goal of the project.

Initially, the test facility design included an unknown suite of wave energy devices. However, it was clear from the onset that this approach created too much uncertainty for agency review. OSU determined it was best to define specific device types to better understand potential environmental effects. OSU included as many device types as possible, but ultimately excluded one in particular, overtopping devices, because of perceived environmental risk. In the final project description, OSU included point absorbers, attenuators, oscillating water columns, and hybrid devices (e.g., horizontal pendulum, rotating mass).

3.2.2. Defining concerns

During initial CWG discussions, concerns expressed were mainly related to the components of a device (such as the type of mooring systems or anchors) or future device designs. Rather than concentrate on these aspects that were difficult to define or may change over time, OSU shifted the thinking to focus on specific effects, or stressor-receptor interactions. Stressors are aspects of the device that may cause harm (e.g., noise from devices or electromagnetic fields [EMFs] from cables) and receptors are the marine animals, habitats, or other users that may be affected by the stressors (Boehlert and Gill, 2010). For example, instead of emphasizing whether a device would have a 3- or 4-point mooring system, the concern was specifically defined as the possibility for slack mooring lines, which could lead to entanglement issues for cetaceans, and particularly for grey whales. The CWG was able to move forward with this shift in thinking and address concerns more efficiently based on stressor-receptor interactions.

With this new perspective, the CWG identified interactions that would need to be considered. Examples included impacts on green sturgeon and their migratory routes, pinniped haul outs, grey whale entanglement, impacts on salmon, effects of EMFs, and boring under a wetland to establish the terrestrial cable route. While agencies added potential concerns to address, the responsibility fell on OSU to find data to reduce uncertainty or explain why a potential effect might not occur. This included bringing forth relevant information and data from research studies, from other ME deployments, or from analogous industries.

Over the years that the CWG convened to meet and discuss PacWave development and operations, many concerns were evaluated. Table 2 provides information about a selection of potential effects discussed by the CWG and the outcomes. Some were initially identified as key concerns but fell away after data were presented showing limited associated impacts. Others either rose in concern over time or were added throughout the process.

3.2.3. Risk-management

All potential concerns were essentially addressed through Protection, Mitigation, and Enhancement Measures (PM&Es) (Oregon State University, 2019a). The PM&Es were grouped into three categories: measures that are implemented based on the Adaptive Management Framework (Oregon State University, 2019b) for which several agencies on the Adaptive Management Committee (AMC) have authority (i.e., all monitoring plans); measures where one primary agency has authority that requires direct consultation for adaptive management; and measures with higher certainty that are not expected to change or require adaptation. The Adaptive Management Framework involves AMC review of the implementation of monitoring plans and associated mitigation and evaluation of potential changes to the current plans based on new information and results derived from operation and monitoring (Oregon State University, 2019b). The AMC comprises representatives of BOEM, FWS, NOAA Fisheries, ODFW, and OSU with the OSU representative serving as the chair. Any action agreed upon by the AMC via consensus voting is to be implemented by OSU. Consensus voting consists of each member casting a supportive or neutral vote or abstaining. If a consensus cannot be reached, a dispute resolution process would then be initiated (Oregon State University, 2019b).

The concerns addressed by the PM&Es and associated actions vary based on the level of risk and/or uncertainty (Table 3). The most robust method was implemented through monitoring plans, which included actionable plans detailing specific methods to monitor for exceedances of set parameters and to mitigate impacts that may occur. Three issues, considered both high uncertainty and high risk, rose to this level of concern: acoustics impacts, benthic habitat impacts, and EMFs (Oregon

Table 2
List of a selection of potential effects discussed by the Collaborative Workgroup. This table is not representative of all concerns.

Category	Potential Issue	Solution
Potential effects that started as a priority, but where concern was diminished through detailed discussion and information exchange.	Green sturgeon migration and electromagnetic field (EMF) effects	Level of concern diminished over several years of discussion and ultimately did not require any plans or measures due to limited effect from project.
	EMF effects from cables	Diminished concern after various reports on EMF were published (Love et al., 2016; Gill et al., 2016). EMF emissions would be minimized by burying cables and shielding cables, umbilical, and other electrical infrastructure. A monitoring plan was created, but no additional mitigation was required for the cable.
	Pinniped haul out	While pinnipeds haul out on many structures in the marine environment and potential impact would be similar to that from all other marine industries, it was a long process to remove this potential effect because of concerns about interactions with pinnipeds when approached for device maintenance or monitoring and increased predation around devices, as well as potential impacts to devices. Practices are in place to minimize pinniped haul out on devices and any project structures.
Issues that rose as concerns over time.	Benthic habitat impacts	Created a monitoring plan to assess benthic habitat impacts from anchors and other equipment as well as from cable-laying and construction activities.
	Organism interaction (fish attraction, predator-prey enhancement)	Did not rise to the level of concern for mitigation, but Oregon State University agreed to develop a monitoring plan to assess any potential organism interactions because monitoring for lost gear entanglement and mooring/anchor integrity using remote operated vehicle surveys could be leveraged to gather data and information on organism interactions.
	Derelict gear	Plan to monitor and remove derelict gear from project structures to minimize risk to marine species from entanglement. Mitigation measures were developed.

Table 3
Example of the characterization of several concerns to responsive action, based on the presence of risk and/or uncertainty. Concerns that required monitoring, mitigation, and adaptive management (both high risk and high uncertainty) were addressed through tailored and rigorous monitoring plans with mitigation measures, shown in yellow (top). Concerns with either high risk or high uncertainty required responsive mitigation actions, shown in orange (middle). Concerns or considerations that need some form of action but did not necessarily require monitoring or mitigation (neither high risk nor high uncertainty) were addressed through prescribed practices, shown in green (bottom).

Concern	High Risk	High Uncertainty	Outcome
Electromagnetic fields	X	X	Monitoring Plans
Benthic habitat impacts	X	X	Monitoring Plans
Sound from wave devices and their mooring systems	X	X	Monitoring Plans
Marine species entanglement/ collision	X		Specific Mitigation Needed
Dynamic positioning vessel activities	X		Specific Mitigation Needed
Approaching pinnipeds hauled out on wave devices and structures		X	Specific Mitigation Needed
Impacts on birds and bats		X	Specific Mitigation Needed
Operations and maintenance			Best Management Practices
Vessel traffic			Best Management Practices
Aquatic resources and threatened and endangered species			Best Management Practices
Recreation, ocean use, and land use			Best Management Practices
Cultural resources			Best Management Practices
Benthic habitat impacts from cable-laying and associated construction activities			Best Management Practices

State University, 2019c).

For example, regarding concerns about acoustic impacts, the Marine Mammal Protection Act drove the development of the monitoring plan because the level of risk was uncertain, and OSU was not able to demonstrate that no injury or harm to marine mammals would be caused (Marine Mammal Protection Act of 1972). Potential effects on marine mammals related to underwater noise may include avoidance of the area, behavioral disruption, interference with communication, prey/predator detection, and impacts on migration (Oregon State University, 2019c; Polagye et al., 2020). In addition to device noise, other potential sources of noise that might affect marine mammals include the sound from project operations (e.g., mooring components), vessels during construction, or environmental monitoring. Examples of responsive actions within the monitoring plan include quantifying sound levels using field measurements and validated sound propagation models, continuing in situ monitoring as long as wave energy devices or mooring systems remain deployed, and notifying NOAA Fisheries if exceedances are detected.

3.3. Authorization

After years of stakeholder collaboration, managing uncertainty, and navigating complex regulatory processes at all levels of government, in May 2019 OSU submitted the Final License Application to FERC for review which included the Applicant Prepared Environmental Assessment (Oregon State University, 2019d). In April 2020, FERC issued its Environmental Assessment with a Finding of No Significant Impact (Federal Energy Regulatory Commission, 2020), designating that PacWave would not have significant environmental impacts—a notable achievement for this novel project.

In January 2021, BOEM issued the seabed research lease for PacWave—the first renewable energy research lease to be offered in federal waters on the West Coast. As a requirement for the FERC license, this allowed the authorization process to move forward. In March 2021, FERC issued the final license for PacWave—the first for a pre-permitted ME test facility.

As OSU waited for final approval for PacWave, design work for construction, particularly the underground cable conduits and subsea cable laying, was initiated in 2020. However, due to delays in the BOEM lease issuance, construction was pushed into 2021. With issuance of the BOEM lease and FERC license, OSU was able to begin construction of the test facility. PacWave is expected to be operational in early 2024 (Fig. 2).

4. Key insights and strategic decisions

As a novel US pre-permitted commercial-scale wave energy test facility, the multi-year PacWave licensing process can provide insights for navigating the US ME regulatory process and managing significant complexity and uncertainty without the benefit of precedent or a well-adapted permitting regime.

4.1. Process decisions

Throughout licensing, key decisions were made, including those about selecting the ALP, defining OSU's role as the project applicant, study and permit sequencing, and collaboration techniques to move efficiently through the process.

4.1.1. Selecting the ALP

The three options for pursuing a FERC hydropower license offer different benefits for applicants and may present different challenges as well. The ILP provides an efficient process through rigid structures and timelines, stakeholder involvement throughout licensing, early scoping to reduce requests for studies and information later, and benefits for projects that involve complex issues or uncertainty. However, the rigid timeline may not be possible for all ME applicants and the overall process may require more time or be more expensive (Levine and Flanagan, 2019). Generally, the ILP is used for re-licensing of traditional hydropower facilities that require less discussion and have few, if any, unknowns—making it an unlikely candidate for permitting new ME developments that have high levels of uncertainty. As seen in the US so far, ME developments have instead chosen either the TLP or ALP (Box 1), which give applicants added flexibility. The TLP has the potential to be both more efficient and less expensive than the ILP, especially for projects that have few concerns or limited complexity (Levine and Flanagan, 2019). Yet, without FERC's involvement or stakeholder engagement in pre-filing issues, additional studies or information requests may arise later in the licensing process. For projects that have a level of certainty, whether in the design or understanding of potential impacts, the ability to have both structure and collaboration can be a useful benefit. The ALP allows for streamlining pre-filing activities (consultation, study, and environmental review) and resolving issues related to early scoping and collaborative stakeholder processes, and allows FERC to serve as an advisor during pre-filing. However, the ALP requires consensus among the applicant and stakeholders regarding studies and settlement agreements, which may be challenging (Levine and Flanagan, 2019).

The ALP was chosen for licensing PacWave—a collective decision by all parties involved as required to use the ALP. For OSU, an important reason for choosing the ALP was the ability to engage FERC from the beginning of the process. FERC not only provided guidance throughout the process, but they also gained a nuanced understanding of how the project developed through agency collaboration. FERC's involvement was particularly useful regarding the CWG; when challenging issues arose or when discussions came to an impasse, the CWG was able to use FERC's experience and receive guidance to move forward. In addition, the flexibility in timeline proved to be valuable relative to the nature of the staged funding availability, and the collaborative process helped achieve the goal of having significant issues resolved when the final license application was submitted. The ALP allowed for agencies to contribute throughout the licensing process, to identify and advise on the management of potential concerns, and to influence the design of PacWave. While OSU recognized this approach may have taken longer, the goal was to resolve issues early through collaboration, which could lead to time and cost reductions later. Overall, the ALP was the best permitting process available to PacWave and enabled OSU to navigate the necessary procedures successfully.

It should be noted that although the ALP accommodates settlement agreements, OSU decided not to engage in a formal settlement agreement to minimize added costs and time. Settlement agreements are often universally approved by all established stakeholders, which affords leverage to parties in order to obtain signoff and agreement. In this case, the goal was to develop a set of commitments for project construction and operational terms by consensus that met parties' needs and that aimed to manage concerns from the outset to avoid unknown issues arising late in the licensing process. This was done through an informal process that mimicked a formal settlement agreement, including conducting negotiations with the agencies within the CWG under a similar premise and framework. However, without a firm commitment of a settlement agreement, there were options for resource agencies to raise residual concerns at the end of the licensing process—options that would otherwise not have been viable if a formal agreement had been in place.

4.1.2. *Defining the applicant*

As a nonprofit institution—a public university and Oregon State's research expert on the marine environment—OSU had an advantage among developers who are commonly perceived as simply seeking commercial opportunity. This afforded OSU credibility in the development of data, studies, and decision-making. This also made OSU conceptually well-placed to operate a facility and broaden the value of the testing work beyond an individual developer's needs.

During the process, the role of research in designing PacWave became a critical question, one that was important in setting boundaries on the purpose of the facility. Because OSU is a research institution with ME knowledge and expertise to further understand and pursue environmental uncertainties related to ME, there was an expectation that work conducted during the permitting, development, and operation of the facility could also advance research objectives. OSU expressly defined PacWave as a test facility, rather than a research facility, in order to set clear expectations that the studies completed as part of PacWave would be only those needed to meet federal compliance for licensing or in conjunction with specific device deployments, rather than conducting research for general knowledge gathering and understanding. Although this was a practical decision for the process timeline and budget, it shifted the perception of OSU's role to one more typical of a project developer. While OSU actively encourages and supports research at PacWave and on/around deployed devices, it was necessary to define the conduct of such efforts to be independent from the regulatory compliance activities required for PacWave.

4.1.3. *Sequencing*

Coordinating local, state, and federal permits is not a simple matter, especially because permits can be interdependent, require redundant information, and have different timelines. Properly sequencing multiple permits or authorizations is critical to efficiently and effectively moving through licensing processes. In the PacWave instance of pioneering a new use of the licensing process, the composite regulatory regime was tested and, in some cases, proved to be imperfectly adapted to an ME project of this nature. Priority for sequencing was based on requirements of the FERC process, and then attempts to tier other state and federal authorizations from that were made.

In addition, the timing of multiple permits or authorizations is not always clearly stated in the statute or rule, so the process is left up to further interpretation. Communicating with agencies about the order of events and information needs, as well as coordinating permitting with federal and state agencies, was crucial and for the most part accomplished successfully. For example, under the Clean Water Act state water quality certifications are needed in order for federal agencies to permit or license an activity that may discharge pollutants (Clean Water Act of 1972). This applies to Clean Water Section 401 and 404 permits issued by the USACE and to FERC licenses. The Oregon Department of Environmental Quality is responsible for the state water quality certificate, and therefore this aspect of the permitting process included enmeshed activities from FERC, Oregon Department of Environmental Quality, and USACE to receive the relevant certificate, permit, and license.

Toward the end of the permitting process, a few unexpected challenges arose in the ALP process. One example was the recommendations filed in 2019 by FWS and ODFW (Federal Energy Regulatory Commission, 2020), which included some new concerns not yet raised as well as others that were resubmitted to be on the record. Under the Federal Power Act Section 10(j) process (Bureau of Ocean Energy Management and Federal Energy Regulatory Commission, 2020), FERC has to assess and respond to each recommendation during environmental review based on the Fish and Wildlife Coordination Act (Fish and Wildlife Coordination Act of 1934). As an outlier to the CWG process, the FWS and ODFW recommendations were able to be filed due to a lack of a formal settlement agreement and were unexpected—a settlement agreement could have avoided such recommendations. Each recommendation required a response from FERC based on their review of and determination about the recommendation. The main concern with the late filed 10(j)s was a delay in authorization for PacWave. In the end the 10(j) process did not affect the project timeline and OSU, FWS, and ODFW were able to proceed after FERC provided its response. This scenario points to the importance for having ongoing discussion and collaboration throughout such a complicated process.

4.1.4. *Collaboration techniques*

A critical piece of navigating licensing was the CWG structure, protocols, and facilitation. Disagreement or inability to agree is common in multi-party collaborations. One way to maintain forward momentum when consensus is lacking is through communications protocols, which anticipate disagreement, rather than require universal agreement to proceed. OSU worked with the CWG to develop such procedures and all CWG members voted in agreement of the final protocol (Oregon State University, 2014). Having an established communication protocol gave the CWG pathways to ensure any disagreement was noted in the record if it could not be resolved.

OSU also hired a professional third-party facilitator to ensure issues were administered fairly (Oregon State University, 2014). As written in the communication protocol, when decisions were required the facilitator asked CWG members to vote with thumbs up, down, or sideways. In order to move forward on a decision, some level of agreement across the CWG was needed, which was defined as no thumbs down votes, or no disagreements (Oregon State University, 2014). The "thumbs sideways" vote became an important factor throughout decision-making because it offered a way for a CWG member to allow a decision to move forward, while acknowledging that they had some reservations.

Communication within an agency was also an extremely important aspect because agency staff serving on the CWG were responsible for relaying concerns, issue management, and negotiations throughout the management chain. Each agency included in the CWG had a staff representative, but the role evolved during the process. Initially, agency representatives voted as subject matter experts about their resource of concern or jurisdictional issue, rather than speaking for their agency in an official capacity. When formal negotiations began, the agency representatives then took on the role of making decisions on behalf of their agency. At this stage, it became crucial to ensure individuals were authorized to represent their agencies to ensure decisions made in the CWG were effective and would not be questioned and re-evaluated at a later point in the process.

One prime example of successful collaboration was the cooperative NEPA process. While the BOEM-FERC joint process states that FERC will lead the NEPA review, developing a joint plan with all relevant federal agencies can further streamline the process (18 CFR §§ 4). After discussing information needs across agencies within the CWG, BOEM, DOE, USACE, USCG, and the National Parks Service agreed to sign on to a cooperative process following FERC's lead for NEPA review (Federal Energy Regulatory Commission, 2020). This allowed for flexibility and efficiency within the NEPA process and also enabled agency evaluation.

Throughout the process, discourse required for decision-making took time, as shown by the almost 10 years it took to authorize PacWave, but in the end it was necessary for collaboration and resolution of concerns. While the formal CWG process concluded with the filing of the Final License Application in 2019, it was clear that continued communication between OSU and the agencies was required. This included making final edits to documents, resolving the Federal Power Act section 10(j) process, and further discussing process options for the agencies and how they would respond to the filings or request additional information or clarification. Ongoing communication and discussion with the agencies was necessary to ensure objectives were met and adhered to until all authorizations were received. In addition, OSU will continue to work with the agencies on the AMC for the duration of PacWave, further exemplifying the importance of continued communication, collaboration, and maintaining productive relationships.

4.2. *Issue management*

The complex nature of authorizing an ME development was heightened when OSU sought to license PacWave as a pre-permitted test facility available to deploy a variety of possible wave energy devices. Issue management throughout the licensing process included defining what constituted an issue, shifting to a focus on interactions, and the ability to use available data.

4.2.1. *Focus on interactions, burden of evidence*

As discussed in Section 3, there was a shift from focusing on specific project components, some of which were unknown (e.g., the specific wave energy devices), to more of an effects analysis focusing on the cause of concern, or the stressor-receptor interactions. This took time and evolved during CWG discussions as concerns were reframed. Once agreed on, the CWG was able to address uncertainty and compile concerns. Stressors were more straightforward to define and consisted of any aspect of the device or system that was added to the environment, either in the water or on land. However, receptors of concern continued to grow as agencies were able to add to the list of potential issues based on perceived impacts. Because OSU sought a collaborative process with open discussion about concerns, there were no boundaries or limits to placing an issue on the list of those to be addressed. However, this quickly became an overwhelming list in need of defining actual versus perceived risks, and the onus was on OSU to provide evidence to remove concerns that were of low/no risk. Rather than listing all potential effects and setting a burden of proof on the applicant as to why an effect is unlikely or not significant, another approach in issue identification could have been to shift from disproving relevance to a modest burden of stakeholders providing evidence to place an interaction on the issue list in the first place. Considering the burden of proof at the outset of issue identification is a critical process feature and allows for distinguishing between actual versus perceived impacts.

4.2.2. *Transferring data based on location, species, and interaction type*

When discussing issues of concern and available information to alleviate these, the ability to use data from a different project or location to inform understanding of potential impacts at PacWave became an obstacle. For instance, BOEM completed a comprehensive report about the effects of EMFs from underwater cables, including field surveys and experiments from in situ cables (Love et al., 2016), and began to present the results to the public. When OSU became aware of such information, they brought the findings to the CWG, whose members were generally reticent about accepting the results prior to the report being published. After the report was published in 2018, the findings were able to be applied to the decision-making process for PacWave and as noted in Table 2, the concern about EMFs from cables diminished due to the findings.

Applying understanding from across the ME industry, and analogous industries in general, can help decrease uncertainty, allow learning from project to project, and increase knowledge to inform decision-making (Copping et al., 2020). Using the best available information can inform understanding and aid decision-making, especially when data and information is scarce. As more ME devices are deployed at locations such as PacWave and beyond, information and learning will increase. The PacWave process shows how lateral use of science can work and be applied successfully to aid understanding; and how adaptive management can be used to allow for forward momentum and information gathering over time.

5. Conclusion and policy implications

Policies to advance clean energy and to decarbonize the electricity sector in response to climate change generally focus on creating economic advantages to installing and operating clean energy. These policies come in a variety of forms, such as production or investment incentives, grants, utility obligations, market preferences, and increasing economic and regulatory pressure on competitive legacy resources. For upcoming, near-commercial technologies such as marine energy, that are not robust enough to be responsive within the traditional economics of markets, such policies are not as applicable, and therefore not effective. Looking ahead, it is apparent that new clean energy technologies with the ability to operate in new locations or to generate power when wind and solar resources are not available will be necessary to meet clean energy goals (Bhatnagar et al., 2021). Stimulating the use of innovative energy resources will require thoughtful research, review, and policy mechanisms for appropriate regulatory frameworks and siting requirements in addition to economic support. Demonstration and deployment are critical to achieving new technology commercialization, yet they face risks, especially where there are greater unknowns in environmental interactions. De-risking development and managing deployment uncertainty and tradeoffs with other policy goals will be essential to delivering the next generation of clean energy technologies into the market. For clean energy policies to be influential in bringing marine energy technologies to commercial stages, policy frameworks must respond to the regulatory, siting, testing, and financial risk aspects of the marine energy sector.

This study offers insights into applicable policy constructs, as PacWave is intended to support marine energy development through these challenging stages. First, regarding regulatory process design, this article conducted in-depth research and reviewed the strategic pathway to secure local, state, and federal authorizations to construct and operate PacWave South, the Oregon State University (OSU) wave energy test facility. With PacWave South receiving a research lease from the Bureau of Ocean Energy Management and a project license from the Federal Energy Regulatory Commission in early 2021, the near-decade-long authorization process ended. Key process decisions included selecting the Federal Energy Regulatory Commissions' Alternative Licensing Process, defining OSU's role as the project applicant, sequencing of various permitting requirements, and collaborating with a variety of agencies and stakeholders. Key management of issues that arose throughout the licensing process included addressing uncertainty regarding wave technologies to be deployed, defining potential environmental effects from wave devices based on causes of concern and focusing on possible interactions, and using available environmental data. These practices allowed OSU to overcome complexity in authorization, including pursuing a new application of the Federal Energy Regulatory Commission's licensing process and addressing uncertainty about potential impacts on the environment, to successfully pre-permit PacWave South. OSU serves as a guide, making decisions regarding licensing processes, stakeholder collaboration, designing and defining the facility, and other key actions that can now be evaluated and applied by the rest of industry. As more wave energy devices are deployed at PacWave South and state and federal agencies continue to be engaged through their agency authorities and OSU's adaptive management process, there will be additional lessons to learn from the experience of OSU and associated stakeholders in this novel application of the US marine energy regulatory regime.

Second, regarding siting and testing, marine energy devices must have validation opportunities at scale and in situ. Developing, deploying, and testing devices demonstrates device feasibility, increases understanding of environmental and socio-economic impacts, and provides fundamental research. In this case study of PacWave South, the authors describe the siting and permitting requirements for a marine energy test facility in which there were considerable unknowns. The path by which OSU achieved authorization for PacWave South is instructive for future regulatory adaptation to address risks and uncertainty with marine energy technologies. This research on PacWave South offers general instruction on energy project regulatory frameworks that manage significant uncertainty, and specific instruction on methods and mechanisms for marine energy to use risk-based approaches and adaptive management to move the industry forward. Such efforts to "learn by doing" will be beneficial, and iterative, in providing additional studies that offer evidence to be used by the regulatory community during future licensing processes, and ultimately for delivering on clean energy goals.

Third, on financial risk management, the PacWave South process also points to barriers and challenges that face the industry. A ten-year permitting process is long, uncertain, and requires adequate support and funding to weather such timelines. The marine energy industry has seen the impact of lengthy timeframes, extensive requirements, and difficulty financing projects; many marine energy companies have fallen under such pressure and marine energy developers have entered permitting processes, sometimes even gained licenses, only to not be able to continue to device deployment (Box 1). Many initiatives within the marine energy industry are working towards uniformity and stability in permitting processes such as through international standards (e.g., International Electrotechnical Commission TC114 for underwater noise measurements (International Electrotechnical Commission, 2019)), developing best practices for environmental monitoring methods and technologies (e.g., Triton initiative (Pacific Northwest National Laboratory)), and using available data to evaluate and deem interactions as low risk (e.g., OES-Environmental (Copping et al., 2020)). Ensuring that regulators integrate and adopt these practices as part of the authorization process should help make permitting procedures more efficient and relieve some of these burdens on the industry. In addition, stable prospective for funding to support and advance research and development, testing, and commercialization of marine energy will be critical to overcome financial challenges. PacWave was successful in part due to the financial investment of the Department of Energy, the State of Oregon, and others. Continuing to provide adequate funding from government entities is necessary to make marine energy a realization as a viable source of clean energy.

Worldwide, permitting processes for marine energy projects will adapt as the industry grows. Cataloging robust and advanced experiences, such as the authorization of PacWave South, will improve the acuity of the marine energy industry's actions, support regulatory adaptations, and help deployments balance the protection of marine resources and user communities with clean energy innovation. This study fills a gap in understanding efforts to navigate the current regulatory regime for marine energy beyond only acknowledging final authorizations received, allowing for an in-depth analysis on the efficacy of it. Sharing insights throughout the entire permitting process, such as challenges faced and successful solutions, rather than only the final accomplishments, helps move the industry forward. As more projects are permitted, the marine energy community would benefit from similar analyses to build a body of knowledge that can inform policy changes or adaptations and provide a regulatory regime that supports and advances marine energy. This will help marine energy become a reality and a valuable contributor in combatting climate change and providing a low-carbon energy source.

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Mikaela C. Freeman: Conceptualization, Investigation, Resources, Data curation, Writing – original draft, Visualization, Supervision, Project administration, Funding acquisition. **Rebecca O'Neil:** Conceptualization, Methodology, Investigation, Resources, Writing – original draft, Supervision, Project administration, Funding acquisition. **Lysel Garavelli:** Data curation, Writing – original draft, Visualization. **Dan Hellin:** Data curation, Writing – review & editing. **Justin Klure:** Data curation, Writing – review & editing.

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Appendix A. Supplementary data

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