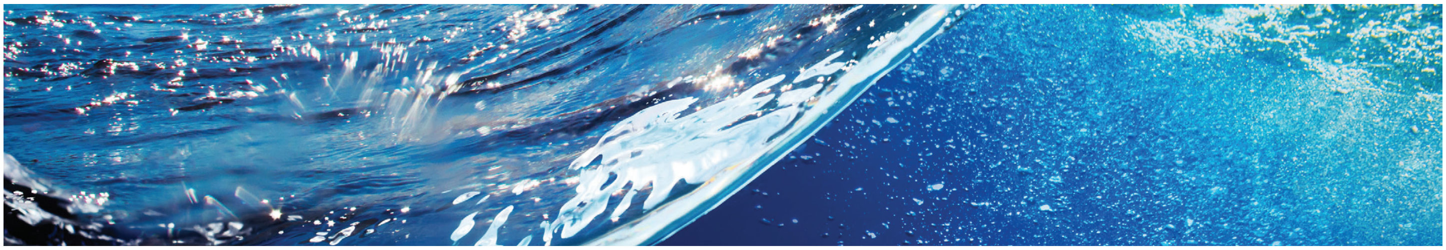

Socioeconomic Impacts of Wave Energy Knowledge and Service Providers to Oregon

Research Summary Report

Prepared for Business Oregon, Winter 2022

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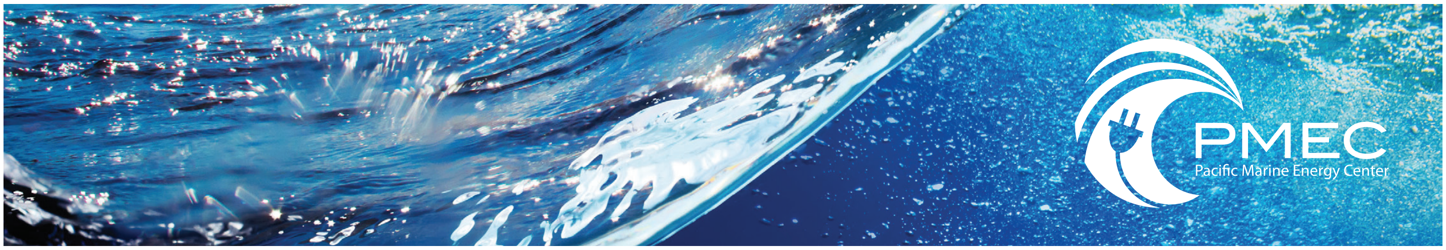


Executive Summary

Winter 2022

INTRODUCTION

Wave energy research and development has been ongoing in Oregon for at least two decades. Substantial interest started in the early 2000's, flattened in the 2010's, and is on the rise again. The Oregon wave energy sector recently experienced several sizable developments in 2020 and 2021, making this a critical moment to examine the status, trajectory, and socio-economic opportunities of the sector. Specifically, in what ways do the facilities and knowledge and service providers at Oregon State University (OSU) facilitate wave energy development in Oregon and beyond? Business Oregon funded a study to answer this timely question, through research that assessed and documented benefits and challenges from both the "supply side" (**providers** of knowledge and services) and "demand side" (**consumers** of this knowledge and these services), described the pre-commercial stage of development, and explained the *current state* and the *trajectory* of the wave energy sector in Oregon. Readers are encouraged to examine the full report to thoroughly understand the study.

KEY FINDINGS FROM DATA ANALYSIS OF PROVIDERS AND CONSUMERS OF OSU KNOWLEDGE AND SERVICES:

Category 1: The Contributions Of, And The Value Added By, Wave Energy Knowledge/Service Providers

KEY FINDING #1: Research Is Fundamental

A key piece of what OSU provides the US, Oregon, and larger wave energy sector is access to state-of-the-art facilities and influxes of research money that spur research and innovation in the sector. Research at OSU is multi-faceted, focusing on the technical, environmental, and socio-economic aspects of wave energy production in Oregon and beyond. Research activities align with needs, including enhancing technological capabilities for wave energy testing and development, knowledge generation, and enhancing the workforce preparation of current and future students. Increased direct investment in research yields innovation, knowledge creation, and training of the future renewable energy workforce.

KEY FINDING #2: Workforce Preparation and Training Drives Future Innovation

Access to state-of-the-art research facilities, and growing research and innovation around these facilities, aids teaching and mentoring of current and future workers in the wave energy sector. 850 undergraduate and 1,452 graduate students learned within 122 wave-energy-related courses between 2017-2021. OSU granted five Bachelor's degrees, 51 Masters' degrees, and 18 PhDs related to wave energy between 2009-2021. Six students participated in internships since 2017 (the majority being DOE funded and outside of Oregon) that involved a range of activities from exploring design optimization, to testing methods of systems and ecological engineering, and community-driven approaches for their usability in system design. These internships indicate that research is closely aligned with industry and companies maintain active relationships with OSU. Graduates landed jobs in a variety of sectors (within and outside of Oregon) including founding some the leading US wave energy technology companies.

KEY FINDING #3: Unique and Knowledgeable Testing Services Enable Innovation

OSU's testing services are individually rare in the U.S., unique in their aggregation in a single location, and are essential to developers as they progress their technology to higher technology readiness levels. Users come from academia, national laboratories, and industry, making these testing services highly desirable for different entities within the wave energy sector. There is high satisfaction with these testing services. Seventy-five percent of the developers interviewed discussed the competitive advantage of having ready access to professional and affordable testing services, and 75% of the developers surveyed discussed plans to test at the PacWave South Test Site (although those plans were contingent on acquiring the funding to do so).

Category 2: Shifts in Focus

KEY FINDING #4: Shift from Commercial Energy Generation to Innovative Knowledge Hub

The perception of the Oregon wave energy sector has evolved and, assuming the status-quo in regional energy system policies, it is uncertain whether Oregon is an ideal near-term economic location for commercial-scale, grid-integrated wave energy generation. Despite the uncertainty expressed over the viability of commercial scale, grid-integrated wave energy generation in Oregon in the near-term, study participants described Oregon as a region with a critical role for wave energy in the U.S. and internationally. Oregon is perceived as a U.S. center for knowledge, research, testing, and development of wave energy, with the potential to attract new developers, bids for services, and export products globally.

KEY FINDING #5: Shift in Markets to Niche Markets such as Blue Economy and Powering Remote Places

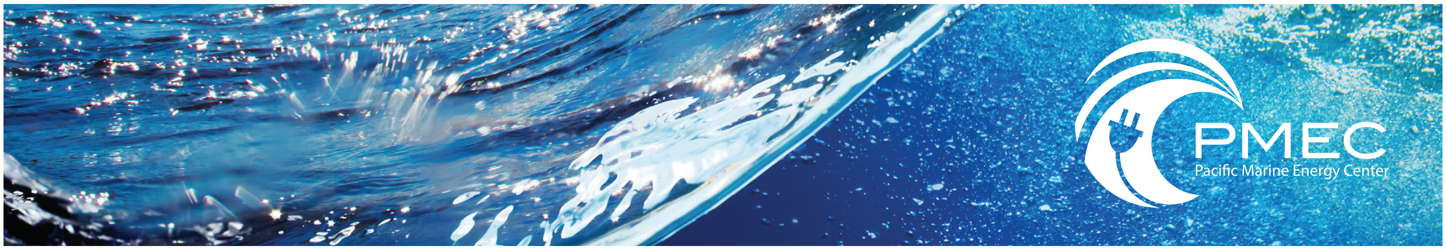
The shift in perception of Oregon as a near-term location for commercial-scale, grid-integrated wave energy generation to a U.S. hub for wave energy innovation and knowledge was accompanied by another shift in the wave energy sector: new applications and markets. This includes Blue Economy applications (such as powering ocean observation stations, aquaculture operations, and autonomous underwater vehicles), powering remote communities (such as coastal communities in Alaska and island communities), and powering desalinization operations. The allure of these new applications was that they could be cost-competitive sooner than commercial-scale, grid-integrated sites.

IMPLICATIONS FOR OREGON'S ECONOMY

Oregon has earned a reputation as the R&D headquarters for wave energy. Investments in wave energy knowledge, innovation, workforce preparation, and testing services are likely to create jobs, establish new businesses, increase tax revenue, reduce poverty, retain rural populations, increase economic resiliency and pathways for under-represented communities, and increase workforce mobility.

NEXT STEPS:

Oregon – with OSU – is *the* innovation and knowledge hub for marine renewable energy technologies. It is, therefore, increasingly important for Oregon to maintain its U.S. leadership position in R&D, workforce generation, and technology innovation. Oregon has the academic and technology development workhorses to secure significant future federal investments if suitable state-level programs are in place. Oregon could ensure the long-term growth of the wave energy sector through increased opportunities for paid student-internship programs at DOE National Laboratories, developers, and a variety of policy making institutions. Finally, wave energy knowledge and service providers' work could enable the *eventual* transition to a commercial phase that could bear even broader socio-economic and natural environment benefits.



Full Report

Winter 2022

A: INTRODUCTION AND BACKGROUND

Wave energy conversion (herein often referred to as wave energy) is an emergent form of marine renewable energy production. Wave energy captures the potential and kinetic energy of the ocean and converts it into electricity or another useful energy source. Wave energy is consistent throughout the year, predictable multiple days in advance, and has higher energy density than solar or wind energy *(1, 2)*. These characteristics offer advantages over other renewables, such as solar which can only produce energy during the day, or wind which is less predictable in advance *(3)*. Despite interest in wave energy dating back to the late 18th century, modern research and development only accelerated over the past few decades. However, as of yet, capturing wave energy reliably and cost effectively at a commerical scale has proven to be an elusive feat of engineering. The ocean presents a harsh and highly variant environment. Modern wave energy technology is still nascent; designs vary considerably and there are no deployments of commercial grid-connected wave energy converters (WECs) in the U.S. and only a few megawatts are generated commercially worldwide *(1)*.

Wave energy research and development in Oregon, however, has been ongoing for at least two decades; substantial interest started in the early 2000's, flattened in the 2010's, but is on the rise again. Why? First, because Oregon has exceptionally high-energy wave resources *(4)*. Second, because Oregon State University (OSU) has numerous research and development facilities, experts in engineering, social science, and environmental studies that specialize in wave energy. Third, because Oregon is home to the majority of U.S. wave energy developers and other supply chain components (e.g., marine industry) that make it a hotbed for wave energy activity.

The Oregon wave energy sector recently experienced several sizable developments in 2020 and 2021, making this a critical moment to examine the status, trajectory, and socio-economic opportunities of the sector. H.R. 133, which was passed in December of 2020, authorized the Department of Energy (DOE) to spend $137 million per year for marine energy over fiscal years 2021-2025. In January of 2021, the Biden Administration replaced the Trump Administration and has prioritized counteracting global climate change and support for renewable energy technologies (*5*). The Biden Adminstration's "Build Back Better" infrastructure plan and these developments could increase funding opportunities for wave energy knowledge/service providers and consumers alike.

Another boon to the sector was the greenlighting of the PacWave South Test Site in Oregon by oversight agencies in early 2021, after almost a decade of effort by the wave energy knowledge/service providers *(6)*. The PacWave South Test Site will be the first pre-permitted, open-ocean, grid-integrated wave energy test site in the U.S., representing a significant milestone for the Oregon and U.S. wave energy sectors. The PacWave South Test Site is planned to be operational in 2024 *(6)*. Furthermore, in mid-2021, the DOE unveiled a $27million funding opportunity announcement (FOA) to accelerate ocean wave energy technology to market, specifically by funding testing at the PacWave South Test Site *(7)*, as well as a $40 million R&D package for National Marine Energy Centers – of which, OSU is the largest center.

There is, therefore, a lot of potential. However, there are also some unknowns and important research questions. Business Oregon sought to better understand the socio-economic benefits of wave energy to Oregon, and supported a study conducted by researchers in the OSU School of Public Policy to find answers to two specific research questions:

(1) In what ways does OSU facilitate wave energy development in OR?
Is it adding direct and indirect value? What kinds? To whom? Does it support the pipeline from "the laboratory test bench to the ocean?", and

(2) Are there strategic and specific "feed-in points" to accelerate technology development and the pipeline?
The study's research strategy was to document and assess the benefits as seen from two sides:

- The "supply side" – the **wave energy knowledge/service providers** who supply the sector with critical knowledge, testing services, workforce education, and other services, and

- The "demand side" – the wave **energy knowledge/service consumers** including technology developers that engage in the entrepreneurial pursuit of designing commercially viable devices, and government and industry-related organizations that utilize the outputs of the wave energy knowledge/service providers.

Study results are interesting and valuable to Oregon policymakers and other key stakeholders of the sector as they anticipate and seek to enhance the socio-economic impacts of the wave energy sector in Oregon. Study results may also be valuable to the global wave energy and renewable energy sectors, as key actors within them seek to optimize a massive transition to low-carbon energy generation in response to global climate change.

It's important to note a few caveats. First, achieving the goals of this study was complicated somewhat by the pre-commercial stage of development of the wave energy sector in Oregon. The wave energy knowledge/service providers support wave energy developers and other members of the sector as, collectively, it matures through a research and development phase before a commercial phase can begin. In addition to generating socio-economic impacts through the current research and development phase of the sector, much of the value of the wave energy knowledge/service providers' work lies in enabling an *eventual* transition to a commercial phase that would bear broader socio-economic impacts. These socio-economic impacts, however, depend heavily on the kind commercial phase that develops. Thus, it's important to think broadly: will Oregon produce wave energy designs for global export, manufacture or construct the devices, or might Oregon play another role entirely within the global wave energy sector? Therefore, evaluating the contributions and impacts of the wave energy knowledge/service providers required an evaluation of both the *current state and the trajectory of* the Oregon wave energy sector.

B: STUDY METHODS

To meet study goals, researchers gathered and analyzed a combination of data from academic archives, existing data sources (Pacific Marine Energy Center (PMEC) and university databases), and conducted 17 structured interviews with key stakeholders in the Oregon wave energy sector (both knowledge/service providers and consumers). The Socio-Political Evaluation of Energy Deployment (SPEED) Framework was used as it is specifically designed to evaluate emergent energy technologies. Creators of this framework *(8)* suggest that the progress of emergent energy technology sectors can be limited by a broad range of factors beyond technical challenges of the technology itself, spanning economic, political, regulatory, and social dimensions that can vary by region. Thus, assessing the progress and trajectory of the Oregon wave energy sector required a regionally-focused, transdisciplinary research approach. To assess the contributions of the wave energy knowledge/service providers and local economic impacts of their work, researchers relied on Grounded Theory *(9)* to guide the exploratory process of this study as the precise contributions and socio-economic impacts were still to be discovered. This ultimately led to building our analysis of regional economic impacts by looking at university spillovers and agglomeration economies *(10)*.

C: LESSONS LEARNED

Results from the research emerged from reviewing the literature and the analysis of existing data sources, and from the analysis of the structured interviews with key stakeholders in the Oregon wave energy sector (**Group 1** - knowledge/service *providers* and **Group 2** - knowledge/service *consumers*). The combined results from this analysis fall into two broad categories, as perceived by both groups.

KEY FINDING #1: Research Is Fundamental

A key piece of what OSU provides the U.S., Oregon, and larger wave energy sector is access to state-of-the-art facilities and influxes of research money that spur research and innovation in the wave energy sector and beyond. Research in the wave energy sector at Oregon State University is multi-faceted, focusing on the technical, environmental, and socio-economic aspects of wave energy production in Oregon and beyond. Group 1's research activities align with Group 2's needs; including enhancing technological capabilities for wave energy testing and development, knowledge generation, and enhancing the workforce preparation of current and future students in wave energy at OSU.

While much of the federal funds invested in Oregon recently (see Figure 1) have been towards funding large-scale infrastructure investments in PacWave (~$5 million annually over the past four years), since 2008 between $1-2 million has been invested annually in funding other research endeavors and funding students.

Annual Funding Directed to PMEC by Source

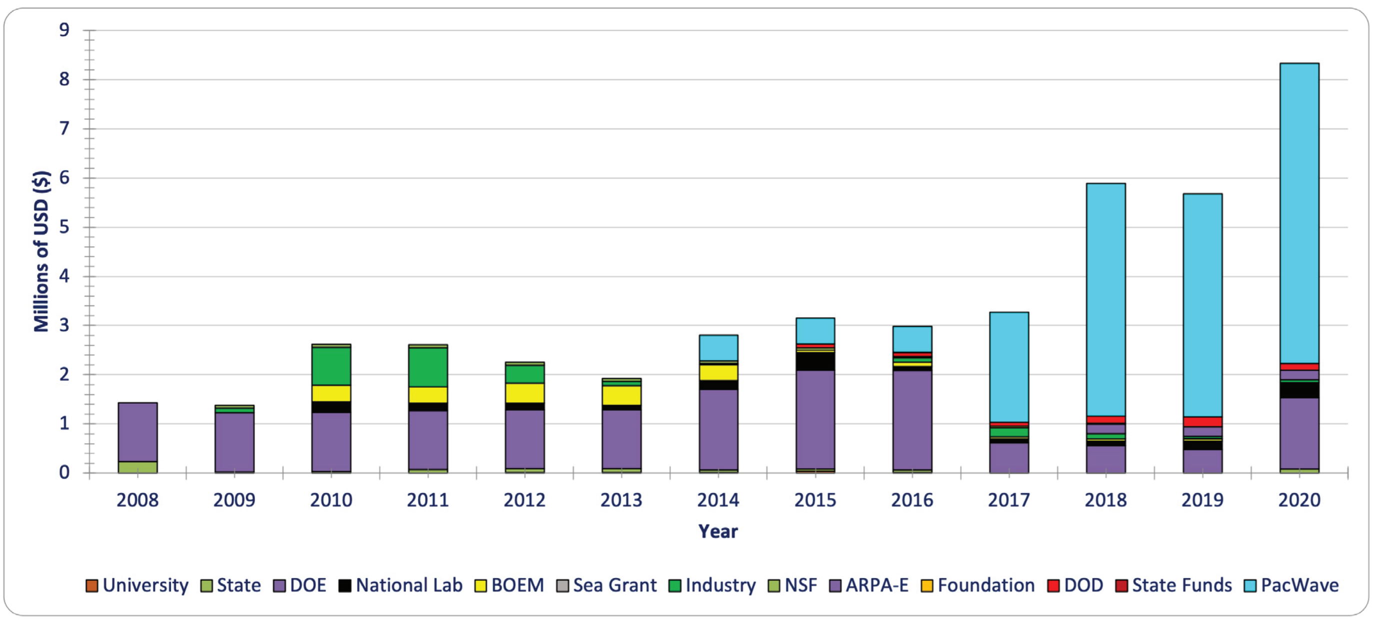


Figure 1

Most notably, the increased non-PacWave funding between 2014-2016 spurred an increase in research output (See Figure 2) along several dimensions including the production of 27 conference papers (2016- 2019) and 34 journal articles (2017-2020). Some of these publications were co-developed with regional and national wave energy technology developers.

Types of Research Produced

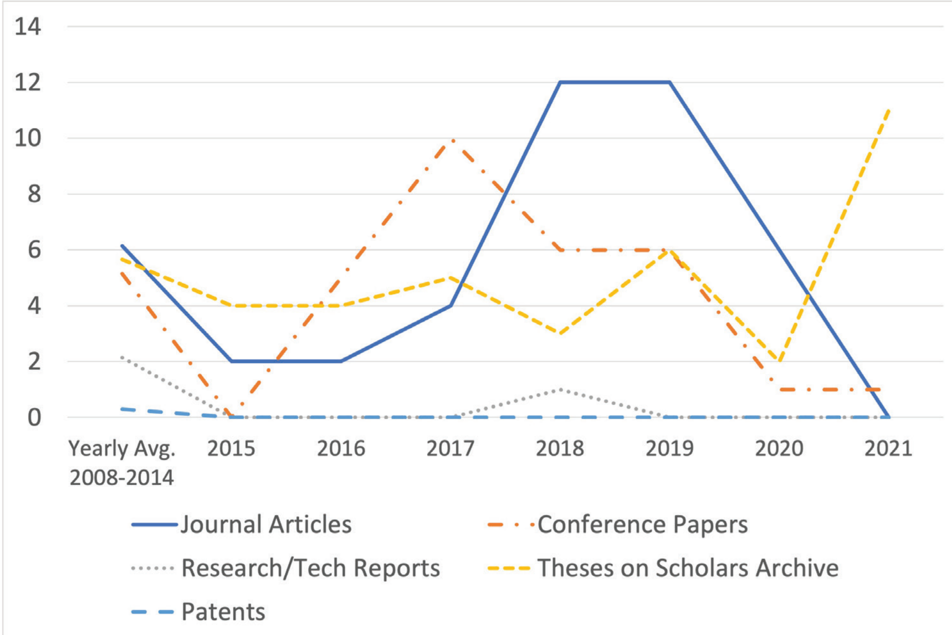


Figure 2

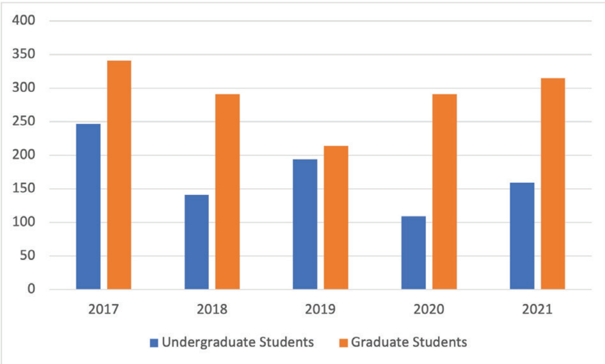
This level of research activity outpaced the average yearly output produced between 2008 and 2014 and suggests that increased direct investment in research projects yields increased innovation, knowledge creation, and training of the future renewable energy workforce. Post-2016, a majority of the funding for PMEC was allocated to PacWave and may have crowded out funding for other research activities – as other funding fell to around the $1 million mark between 2017-2019 – potentially leading to the reduction in research output (along with publication lags) in 2020. Current tallies for 2021 and expected 2022 research funding show an increasing trend.

Despite this crowd-out between 2017-2019, the large-scale investment in PacWave South is likely to yield increases in research expenditures and associated output over the long-term. A majority of study respondents expressed optimism that the number of research projects would increase over the next 10 years. Previous research has shown that the establishment of university affiliated research facilities, like the PacWave South Test Site, can boost regional innovation. Pfister et al. (*11*) found a 6.8% increase in regional patenting activity and an increase in patent quality of 9.7% (measured by patent family size, and the number of claims, and citations per patent) after the establishment of research universities in applied sciences in Switzerland. Helmers and Overman (*12*) show that around 8.36 extra articles per year were produced after the establishment of the Diamond Light Source synchrotron in the UK.

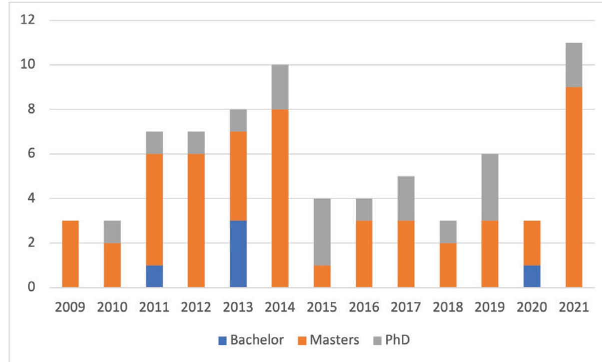
KEY FINDING #2: Workforce Preparation and Training Drives Future Innovation

Access to state-of-the-art research facilities, and growing research and innovation around these facilities, aids teaching and mentoring of current and future workers in the wave energy industry and beyond. As evident in Figure 4, between 2017 and 2021, OSU taught 850 undergraduate students and 1,452 graduate students across 122 wave-energy-related courses during that span. Between 2009 and 2021, OSU has granted five Bachelor's degrees, 51 Masters' degrees, and 18 PhDs related to wave energy. A majority of study respondents suggested that student numbers would maintain or increase over the next 10 years. Another area of expected growth in workforce preparation is internships. Since 2017, six students have participated in internships, the majority of which have been DOE funded and outside of Oregon. These internships have involved a range of activities from exploring design optimization of small-scale WECs to testing methods of systems engineering, ecological engineering, and community- driven approaches for their usability in wave energy system design. These OSU student internships indicate that research is closely aligned with industry and companies maintain active relationships with OSU.

Wave Energy Related Course Enrollments



Degrees Granted



Location of Alumni Jobs

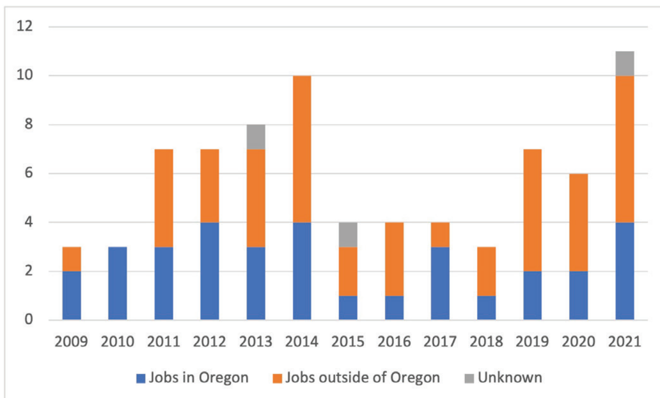


Figure 3

OSU graduates have gone on to jobs in a variety of sectors within and outside of Oregon. As noted in Figure 3, around 43 percent of graduates since 2009 have found jobs or have continued their education in Oregon. Around 20 percent of graduates have continued in academic or research positions as either an instructor, post-doc, or PhD student at universities or national laboratories across the country. One student who graduated from OSU in 2020 is currently a post-doctoral researcher at the National Renewable Energy Laboratory in Boulder, Colorado. Another set of students have gone on to positions in state and local government, including one who is currently a Radioactive Waste Remediation Specialist at the Oregon Department of Energy. Finally, students have also found jobs in the private sector, including one who is the Oregon Policy Manager at Renewable Northwest in Salem, Oregon. Additionally, OSU students have also founded some of the leading U.S. wave energy technology companies, including Aquaharmonics, a recent recipient of the $1 million U.S. DOE 'Wave Energy Prize'.

KEY FINDING #3: Unique and Knowledgeable Testing Services Enable Innovation

Testing services provided by OSU research facilities are the key to enabling this growing innovation and likely play a key role in attracting wave energy developers to Oregon. Group 1 offers testing services that are individually rare in the U.S., are unique in their aggregation in a single location, and are essential to developers as they progress their technology to higher Technology Readiness Levels (TRLs). As noted in Table 1, these users come from academia, national laboratories, and industry, making these facilities' testing services highly desirable for different entities within the wave energy sector. Half of the developers interviewed had used the large wave flume at the O.H. Hinsdale Wave Research Laboratory (HWRL) to test scaled-down prototypes of their WEC designs. The facility was described as one of only two accessible facilities in the U.S. for wave flume testing. Over the past five years, users of the HWRL were often small entities – averaging around five employees – that conducted between two and eight short-duration (between 6 and 28 days) testing projects a year. Additionally, half of the developers interviewed had conducted electrical systems testing at Wallace Energy Systems & Renewables Facility (WESRF). Over the past five years, users of the WESRF were also often small entities – averaging around five employees – that conducted between one and three long-duration (between 180 and 360 days) testing projects a year.

O.H. Hinsdale Wave Research Lab (HWRL)

Year	# of Testing Clients	Type of Businesses	Average number of employees	# of Projects	Average # of days per project
2021	7	Industry, Academia	5.33	8	16
2020	2	National Lab	8	2	28
2019	4	Industry	3.5	5	6
2018	3	Industry	5.66	6	6
2017	3	Industry	4.33	8	15

Wallace Energy System and Renewables Facility (WESRF)

Year	# of Testing Clients	Type of Businesses	Average number of employees	# of Projects	Average # of days per project
2021	3	Industry, National Lab	5.66	3	360
2020	2	National Lab	8	1	180
2019	1	National Lab	8	1	180
2018	2	Industry, National Lab	4.5	2	360
2017	1	Industry	2	1	180

Table 1

The developers that had utilized these testing services discussed high satisfaction with the facilities themselves, the experts running them, and the easy accessibility of the services. One developer in particular noted the importance of these facilities to the success of small companies, which make up a majority of the current testing clients (see Table 1), stating:

> *"Regarding Hinsdale, when [my company] was at an early stage of learning about our tech, it was just absolutely critical to have wave tank testing and to have it at a relatively low cost...the informality of just having the ability to arrive and use their machine shop for the stuff we needed, and you know, work in real time and have it be relatively flexible with timing and schedules...all of those intangibles are just so critical when you're a small company. It would have been virtually impossible to develop the tech at that stage without some wave tank of that depth, with those capabilities."*

Overall, 75% of the developers interviewed discussed the competitive advantage of having ready access to the professional and affordable testing services that Group 1 offers and, although developers outside Oregon still make use of these specialized services, developers located in Oregon described the proximity as a compelling reason for locating there. One developer said:

> *"We're in Oregon because access to those two facilities [Hinsdale and WESRF]; so that we can rapidly test."*

Seventy-five percent of the developers discussed plans to test at the PacWave South Test Site, although those plans were contingent on acquiring the funding to do so. Another developer located outside Oregon discussed tentative plans to open an office in Oregon specifically to take full advantage of the OSU testing services provided by the wave energy knowledge/service providers (particularly the PacWave South Test Site). The 2021 $27M DOE FOA (*7*), which explicitly supports device construction, testing and research at PacWave South Test Site, should enable developers to make use of the South Test Site once it's operational.

KEY FINDING #4:
Shift from Commercial Energy Generation to Innovative Knowledge Hub

In the 2000's and early 2010's, wave energy researchers and developers were focused on Oregon as a site for commercial-scale, grid-integrated wave energy electricity generation. Economic analyses estimated that the statewide socio-economic impacts of a 500 MW wave energy farm off the coast of Oregon would include creating 13,000 new jobs, an increase in economic output of $2.4 billion, and an increase in state tax revenue of $90 million (*13*). Another analysis noted that the economic impacts of deploying 13,000 MW of WEC installations off the coast of Oregon from 2026 to 2045 would yield 5,500 jobs annually from 2026 to 2045 and support a total of $1.4 billion in economic activity by 2045 through construction and installation, with WEC operations yielding an additional $0.6 billion in annual economic activity for the lifetime of the WECs and $7.4 million in annual lease payments to the State of Oregon (*14*). However, the results of this study indicate that the perception of the Oregon wave energy sector has evolved and, assuming the status-quo in regional energy system policies, it is uncertain whether Oregon is an ideal near-term economic location for commercial-scale, grid-integrated wave energy generation.

Study participants across both groups discussed several challenges to commercial-scale, grid integrated wave energy generation in Oregon. Sixty-nine percent of the study participants discussed the competitive energy market conditions in Oregon, most notably cheap energy sourced from natural gas and considerable hydropower, that make cost competitive commercial-scale, grid-integrated wave energy challenging. Additionally, Group 1 respondents noted the rapid growth of solar and particularly offshore wind, which present more mature renewable energy alternatives with high potential outputs within a couple decades, relative to the more nascent stage of the wave energy sector. Group 1 respondents also suggested wave energy may always be more expensive than solar and wind options, due to the extreme challenges of working in the ocean environment with devices that must operate largely underwater.

However, they also noted that wave energy could become more cost-competitive if future energy pricing accounts for the externalized costs of fossil fuels, if renewable energies see greater government incentives, and as the greater energy system strives towards significant renewable energy proportions. Group 1 also noted strengths and intrinsic values of wave energy to Oregon, such as its usability throughout the day and night, high predictability relative to other renewables, and coastal generation location (*also described by 1, 2, and 3*) which could make wave energy more valuable to the grid per watt and the importance of resiliency and having a diversified energy portfolio, which could emerge as factor beyond cost that favors a mixed energy profile containing wave energy.

Despite the uncertainty expressed over the viability of commercial scale, grid-integrated wave energy generation in Oregon in the near-term, study participants described Oregon as a region with a critical role for wave energy in the U.S. and internationally. Oregon was perceived as a U.S. center for knowledge, research, testing, and development of wave energy, with the potential to attract new WEC developers, bids for services, and export products globally.

KEY FINDING #5:
Shift in Markets to Niche Markets such as Blue Economy and Powering Remote Places

The shift in perception of Oregon as a near-term location for commercial-scale, grid-integrated wave energy generation to a U.S. Wave Energy Innovation Hub was accompanied by another shift in the wave energy sector. New applications and markets, aside from commercial-scale, grid-integrated energy generation and sale, have emerged over the past few years. Seventy-one percent of study participants discussed the expansion of applications and markets for wave energy beyond commercial-scale, grid-integrated power generation. Such applications and markets include emergent Blue Economy applications (such as powering ocean observation stations, aquaculture operations, and autonomous underwater vehicles), powering remote communities (such as coastal communities in Alaska and island communities), and powering desalinization operations. The allure of these new applications was that they could be cost-competitive sooner than commercial-scale, grid-integrated WEC sites. Additionally, for some of these new applications, either no alternative powering options are viable (for instance, for remote oceanic observation and vehicle charging) or the cost of energy in these new markets is already very high. For instance, in remote and island communities that rely on expensive diesel shipments for power, wave energy could compete more easily.

D: WHAT DOES THIS MEAN FOR OREGON'S ECONOMY

In the near term, testing, application, and markets for wave energy are either at PacWave or outside of Oregon. Oregon has a well-earned reputation as the R&D headquarters for wave energy developers and associated industries (an example of agglomeration economics), that will continue to grow. Yet, what do these results mean for Oregon's economy?

The economic impacts of investments in wave energy knowledge, innovation, workforce preparation, and testing services are likely to include job creation, new businesses established, increased tax revenue, poverty reduction, rural population retention, an increase in economic resiliency, pathways for under-represented communities, and increased workforce mobility. Previous research (*15*) suggests that these types of economic spillovers are also highly localized, often found within 150 miles of universities and research facilities where the research, workforce preparation, and testing services occur. This suggests that much of the spillover socio-economic impacts of projects, such as PacWave South, are likely to stay in Oregon.

In terms of research, previous studies provide estimates relevant to projecting the regional economic impacts of Group 1's research. Hausman (*16*) found that following the Bayh-Dole Act, and subsequent increases in federal funding of university research in the U.S., industries located near universities that conduct relevant research experienced increases in employment, payroll, and wages (with magnitudes of 18.14 employees and a 0.4% wage increase per county-industry). Kantor and Whalley (*17*) also found an increase in local wages near universities, although they measured wages across sectors, not just in sectors associated with university research. Kantor and Whalley (*17*) found that a 1% increase in university expenditures increases local labor income in other sectors by 0.08%. Furthermore, Kantor and Whalley (*17*) found that cumulative spillover effects doubled when local universities are more intensively focused on research. Overall, the Oregon Ocean Innovation Hub analysis (*18*) suggests that investments in innovation and entrepreneurship, which Group 1's research patently supports, are likely to generate $5 in economic impacts to Oregon for every $1 invested.

In terms of workforce preparation, numerous studies have shown that gaining better access to a specialized workforce is a powerful mechanism for agglomeration economies and can attract businesses to a region (*16; 15; 21*). In addition to attracting businesses, the subsequent increased presence of science, technology, engineering, and math (STEM) and non-STEM graduate workers was found to increase local wages of graduate and non-graduate workers (*22*). Winters (*22*) found that in addition to graduates accruing higher salaries themselves, a one percentage point increase in the population with a STEM degree increased the wages of non-college graduates by 1.31%, and a one percentage point increase in non-STEM graduates increased the wages of non-college graduates by 0.29%. Furthermore, a one percentage point increase in STEM graduates increased the wages of all STEM workers in the region by 1.97%. Overall, Winters' (*22*) analysis suggests that by producing graduates, ideally that stay in Oregon for wave energy work such as WEC development, Group 1 is increasing local wages of college graduates and non-graduates in Oregon. Overall, according to the Oregon Ocean Innovation Hub analysis (*18*), investments in the Blue Economy workforce via support for primary, secondary, and post-secondary education will generate $4 in economic impacts to Oregon from each $1 invested. This return ratio offers the best available estimate of what OSU's training services in wave energy beget in economic impacts to Oregon.

In terms of testing services, the advantages described by Group 2 study participants of locating proximal to the specialized testing services provided by Group 1 align with past research on agglomeration economies, which suggest that access to specialized services can drive firms to locate nearby (*16; 19; 20; 21*). Attracting new developers is expected to produce several economic impacts, including job creation (*16*) and increased tax revenues (*21*). Future research should monitor the impact of the PacWave South Test Site's completion on the location of new developers in Oregon to gain a better sense of the magnitude of this agglomeration economy. Furthermore, it is clear from the feedback from developers that the testing services offered by Group 1 are essential to the innovation and entrepreneurship of their firms, which the Oregon Ocean Innovation Hub analysis (*18*) values at $5 in economic impacts to Oregon for every $1 invested.

NEXT STEPS:

This study presented analysis of historic and present-day data and policy directions. However, as global energy investments and government policies shift toward new opportunities for climate resilient economic growth, there is an opportunity for new renewable energy technologies that could materialize growth in new sectors. This growth has already occurred for terrestrial solar and wind – where significant expansions in technology deployments and cost decreases were not predicted by industry experts based on historical (pre-2010) data. As such, it is increasingly important for Oregon (and OSU) to maintain its U.S. leadership position. This is true in terms of research and development, workforce generation and technology innovation. This will be done by closely following international technology trends and federal incentives, and by creating opportunities to ensure technology and supply chain companies continue to see the region as the 'place to be'.

Despite significant political and ideological changes in the U.S. Government, it is important to note that wave energy has significant support from both sides of the political aisle. Wave energy is seen as an opportunity for domestic innovation and part of our new energy landscape. It is expected that federal investments in the marine energy sector will continue to grow in-line with historical investments in wind and solar. Oregon has the academic and local technology development workhorses to secure a significant portion of these federal investments if suitable state-level programs are in place to support the development and expansion of the sector.

OSU is responsible for training of many of the future renewable energy leaders. Increased opportunities for paid student-internship programs at DOE National Laboratories, developers, and a variety of policy making institutions would ensure the long-term growth of wave energy. Oregon – with OSU – is *the* Innovation and Knowledge Hub for marine renewable energy technologies. In addition to generating near-term socio-economic impacts (through the current research and development phase of the sector), wave energy knowledge/service providers' work could enable the *eventual* transition to a commercial phase that could bear even broader socio-economic and natural environment benefits.

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