Economic Impacts of Wave Energy to Oregon's Economy

A Report to Oregon Wave Energy Trust

Final Report

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ECONorthwest
ECONOMICS • FINANCE • PLANNING

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About Oregon Wave Energy Trust

Oregon Wave Energy Trust (OWET) – with members from fishing and environmental groups, industry and government – is a nonprofit public-private partnership funded by the Oregon Innovation Council in 2007. Its mission is to serve as a connector for all stakeholders involved in wave energy project development – from research and development to early stage community engagement and final deployment and energy generation – positioning Oregon as the North America leader in this nascent industry and delivering its full economic and environmental potential for the state. OWET's goal is to have ocean wave energy producing 2 megawatts of power – enough to power about 800 homes – by 2010 and 500 megawatts of power by 2025.

Acknowledgements

This report was prepared by ECONorthwest's Portland, OR office for OWET. Dr. Stephen Grover was the project manager for the analysis and any questions or comments should be directed to him by e-mail at grover@portland.econw.com or by phone at (503) 222-6060. Alec Josephson conducted all of the impacts modeling. ECONorthwest staff members Robert Whelan, Jessica Smith, Alex Reed, and John Boroski also assisted with the analysis.

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1. INTRODUCTION

Around the world there is growing interest in harnessing the power of the ocean to produce renewable, carbon-free electricity and some researchers have speculated that a significant portion of global energy demand could be supplied through various forms of ocean energy (waves, tides) in the future.

Compared to the wind and solar energy industries, however, ocean wave energy technology is still in a very young development phase. Many types of wave energy conversion devices are being conceptualized and designed, and none have yet been deployed on a large scale. Currently, three leading design platforms are horizontally-floating, cylindrical "sea-snakes", vertically floating buoys, and onshore devices that use wave energy to move oscillating metal flaps. Future wave energy facilities that utilize variations of these designs are currently planned in Portugal, Scotland and England, and also in California and Oregon.

Oregon has been identified as having significant potential for wave energy production based on its substantial wave resources and existing coastline transmission facilities. Given this potential, this study was commissioned by OWET to determining the possible economic benefits to Oregon and Oregon's coastal communities from having a thriving wave energy industry located within the state.

While wave energy industry growth will proceed along a continuous path, this study examines the economic impacts at three distinct points in time. Specifically, this study estimates the economic impacts of the wave energy industry at the following stages of industry development:

1. **Research and Development (R&D) Stage**. This stage analyzes the economic impacts of constructing and operating a wave research & development facility on the Oregon coast. This stage also includes the construction, installation, and operations of prototype wave energy buoys.

2. **Commercial Stage.** This stage will address the economic impacts of constructing and operating a 500 MW wave farm off the coast. Impacts at this stage will be from construction, operations and maintenance, and power generation.

3. **Industrial Stage.** This stage examines economic impacts of developing and operating a manufacturing cluster that provides wave energy equipment and expertise to other national and international markets.

In order to limit the focus of the economic impact analysis, three distinct points of wave energy development have been chosen for analysis along a continuous development timeline. Note that there will need to be a significant amount of development activity between the three stages included in this report. When moving from the R&D stage to the Commercial Stage, for example, there will need to be series of progressively larger prototypes and smaller scale wave energy farms before the industry is able to install and operate a 500 MW facility at a competitive cost. Additionally, the 500 MW point was chosen as this has been set as one OWET's wave energy industry goals.

The IMPLAN input-output model was used to estimate the economic impacts for each of these wave energy industry phases. Economic impacts were estimated for both the construction and operations phases for each industry stage. Additionally, the potential economic impacts in each stage were estimated for Oregon's coastal economy (defined in this study as Lincoln, Douglas, and Coos counties). We also examine economic impacts for the entire state of Oregon, as some services (e.g., engineering, legal, manufacturing) will be provided from non-coastal communities.

An additional component of this analysis is to describe the economic contribution of coastal fisheries to Oregon, as the fishing industry could potentially be affected by wave energy farms. For this task, we summarized the results of existing economic studies of Oregon's fishing industry. We did not attempt to predict how wave energy could impact the coastal fishing industry, as additional research is needed to determine the type and magnitude of possible impacts. Instead, by presenting the economic impacts of the fishing industry and the wave energy industry together, we lay the groundwork and provide context for future research on this topic.

In the process of developing this report, ECONorthwest reached out to a wide range of stakeholders and market actors involved with wave energy and related industries. As part of the background research for this report, we spoke with people from the following organizations:

- The U.S. Department of Energy
- EPRI
- Oregon Dungeness Crab Commission
- Argos, Inc
- Ecotrust
- Douglas County
- Tillamook County
- Lincoln County
- Ocean Power Technologies (OPT)
- The Research Group
- Oregon Employment Department

The people interviewed were all very helpful in providing input and feedback on the assumptions made for this report regarding the wave energy and fishing industries. It is important to note, however, that these agencies do not necessarily agree with or endorse the research methods and conclusions presented in this report.

Details on the analysis methods and economic impact estimation results are presented in the remainder of this report.

2. ANALYSIS METHODS AND DATA SOURCES

DATA SOURCES

An initial task of this project was to develop the cost and spending assumptions for each of the three wave energy industry phases. Once these cost and spending assumptions were developed, they were used as inputs for the economic model used to estimate economic impacts.

For this study, ECONorthwest developed cost and spending estimates for the wave energy facilities using information from the following sources:

- Electric Power Research Institute (EPRI) Report: System Level Design, Performance and Costs – Oregon State Offshore Wave Power Plant. November 30, 2004
- 2002 Economic Census
- U.S. Department of Energy projected energy costs
- U.S. Department of Labor's Covered Employment and Payroll data, accessed through the State of Oregon's OLMIS website
- Industrial lease rate quotes from the Oregon coast
- Bureau of Labor Statistics Wages by Area and Occupation
- 10-K reports of McDermott International and General Electric
- 2007-2008 annual report of Ocean Power Technologies, Inc.
- Mr. George Wolff of Ocean Power Technologies, Inc.
- Mr. Mirko Previsic, principal investigator for the November 2004 EPRI report

In addition to data on wave energy, this report also relies on other studies to describe the economic contributions of the commercial and recreational fishing industry on the Oregon Coast. The economic impact of Oregon's commercial industry is modeled by fishery economists at The Research Group, a firm located in Corvallis, Oregon. The Research Group uses a proprietary input-output tool derived from IMPLAN, called the Fishery Economic Assessment Model (FEAM), to model the economic impacts of the fishing industry on the Oregon economy. FEAM was originally developed by Hans Radtke and William Jensen for the West Coast Fisheries Development Foundation in 1988 and the model has been continually refined.[1] The Research Group writes a biennial report for the Oregon Department of Fish and Wildlife called "Oregon's Commercial Fishing Industry" that details the results of this model. We summarize the results of the most recent report for the year 2006.

[1] Hans Radtke is also a founding member of The Research Group.

For the contributions of the recreational fishing industry, we summarize IMPLAN modeling findings that were presented in the most recent "Sportfishing in America" report published by the American Sportfishing Association.

IMPLAN MODEL

The primary focus of this study was to estimate the potential economic impacts at several different stages of wave energy industry development (e.g., R&D, commercial, industrial). The economic modeling framework that best measures the economic impacts is called input-output modeling. Input-output models provide an empirical representation of the economy and its inter-sectoral relationships, enabling the user to trace out the effects (economic impacts) of a change in spending for goods and services within the study area.

Input-output analysis employs specific terminology to identify the different types of economic impacts resulting from economic activities: direct impacts, indirect impacts, and induced impacts. Expenditures made to construct and operate the wave infrastructure affect the Oregon economy *directly*, through the purchases of goods and services in this state, and *indirectly*, as those purchases, in turn, generate purchases of intermediate goods and services from other, related sectors of the economy. In addition, the direct and indirect increases in employment and income enhance overall economy purchasing power, thereby *inducing* further consumption- and investment- driven stimulus. This cycle continues until the spending eventually leaks out of the local economy as a result of taxes, savings, or purchases of non-locally produced goods and services or "imports."

Because input-output models generally are not available for state and regional economies, special data techniques have been developed to estimate the necessary empirical relationships from a combination of national technological relationships and county-level measures of economic activity. This modeling framework, called IMPLAN (for IMpact Analysis for PLANning), is the technique that ECONorthwest has applied to the estimation of impacts.[2]

The IMPLAN model reports the following economic impacts:

- *Total Industrial Output (Output)* is the value of production by industries for a specified period of time. Output can be also thought of as the value of sales including reductions or increases in business inventories. It is the broadest measure of economic activity, and includes purchases by businesses of intermediate goods and services, as well as the total value added during production. (Total value added is discussed below.)

[2] IMPLAN was developed by the Forest Service of the US Department of Agriculture in cooperation with the Federal Emergency Management Agency and the Bureau of Land Management of the US Department of the Interior to assist federal agencies in their land and resource management planning. Applications of IMPLAN by the US Government, public agencies and private firms span a wide range of projects, from broad, resource management strategies to individual projects, such as proposals for developing ski areas, coal mines, and transportation facilities, and harvesting timber or other resources. ECONorthwest has applied the model to a variety of public and private sector projects including an analysis of the economic impacts of the Energy Trust of Oregon's energy efficiency and renewable energy programs.

- *Employee Compensation (Wages)* includes workers' wages and salaries, as well as other benefits such as health and life insurance, and retirement payments, and non-cash compensation.
- *Proprietary Income (Business Income)* represents the payments received by small-business owners or self-employed workers. Business income would include, for example, income received by private business owners, doctors, accountants, lawyers, etc.
- *Other income* includes payments to individuals in the form of rents received on properties, royalties from contracts, dividends paid by corporations, and profits earned by corporations.
- *Production business taxes* are taxes paid by businesses to local, state, and federal taxing jurisdiction. In Oregon, production business taxes consist primarily of property taxes, and approximately 85 percent of the production business taxes paid accrues to state and local taxing jurisdictions. The remainder goes to the federal government.
- *Total value added* is the sum of wages, business income, other income, and production business taxes. Total value added is a component of output, and the two should not be added together. In addition, total value added is a close approximation of gross state product.
- *Job* impacts include both full and part time employment.
- *State and local taxes* include production business taxes (discussed above) as well as personal income taxes; social insurance (employer and employee contributions) taxes; and various other taxes, fines, and fees paid by businesses and households.

Our IMPLAN results estimate the net economic impacts of the wave industry on the Oregon economy relative to a base case scenario where a wave energy industry is not developed within Oregon. As discussed previously, we have not attempted to estimate how an Oregon wave energy industry might adversely affect existing industries such as fishing or tourism.

The following section presents the cost input assumptions used in the IMPLAN model for each of the three wave energy industry phases.

3. WAVE ENERGY MODEL INPUT ASSUMPTIONS

This section of the report describes key expenditures and employment assumptions associated with three distinct points along the wave energy industry development timeline (R&D, 500 MW commercial facility, industrial). For each of these three phases, we developed cost estimates for both the construction and operations phase for a total of six different sets of economic impact estimates.

For certain industry stages, notably the operations phase of an R&D facility, we had access to specific spending data that allowed us to disaggregate expenditures into relatively fine sectoral detail. For most stages, however, available expenditures data are non-specific and we had to divide expenditures across several logical industries. While a commercial wave farm would likely buy production inputs from 50 different industrial manufacturing sectors and perhaps 20 different business services sectors, we divided expenditures into fewer categories to make the modeling task more tractable. As the multiplier effects for these industries is similar, we do not believe that this aggregation significantly affected the analysis results.

The first task in this process was to develop cost estimates for the various wave energy industry stages. While some wave energy research has been done by EPRI, the cost estimates are primarily theoretical in nature as there are presently no large-scale, commercially viable wave energy facilities operating in the world today. In order for wave energy to become commercially viable, the costs of constructing wave energy facilities will need to decrease substantially from their current estimates in order to make wave power competitive with other sources of renewable energy.

To understand how industry costs would decline over time in order for wave energy to become commercially viable, a simple financial model was developed to determine the discount from EPRI's estimated long-run costs that would provide large, future projects a return-on-investment (ROI) of 15 percent. The following assumptions were used:

- The project would be a central Oregon coast 500 MW wave farm
- The project would have a capacity factor of 30 percent
- Power would be sold for $63 per MW (2008 dollars)[3]
- Construction would occur in year one
- Major parts replacements would occur every tenth year
- Annual overhead costs would be $5 million

[3] This is the avoided cost for new renewable plants in the Northwest in 2030 (adjusted for inflation to 2008 dollars) for wind power as reported in the "Annual Energy Outlook 2008" by the Energy Information Administration (page 71).

The ROI model revealed that the costs of future wave farm construction and operations, as delineated in the EPRI report, would need to decline 72 percent overall. This cost adjustment was applied to the construction and operations of the 500 MW wave farm. Costs of established elements, such as onshore transformers and cables, were reduced by 50 percent and costs of other elements were reduced by more than 72 percent, assuming that productivity gains would be greatest for wave energy specific products.

Note that these cost estimates are designed to provide a realistic yet conservative estimate for the conditions that would need to occur in order to attract investment in a wave energy facility of this size. As a result, our financial model requires that significant cost reductions occur prior to the 500 MW facility being built. We have also assumed that the cost of power produced by the wave facility would be comparable to the expected future cost of wind power. Our assumptions do not include any green power price premium that wave energy power may be able to command. Consequently, our estimates are more conservative than what may actually occur should wave power be sold at a premium over other renewable energy sources such as wind. The combined result of these assumptions is a construction cost estimate of about $750,000/MW to construct a 500 MW facility in Oregon. To the extent that wave power can be sold at a higher price or if the facility can be built at a higher cost and still sell power at a competitive price, then the economic impacts reported here will be lower than what might be achieved under these conditions. Alternative cost scenarios using higher cost assumptions are also discussed later in this report.

We also needed to select a location for the development stages so that lease rates, wages, property taxes, and utilities costs would be consistently applied. We chose Reedsport in Douglas County because it is in the center of the region being analyzed and, according to EPRI, a logical place to site a wave energy farm.[4] In reality, the industry stages could locate elsewhere along the central coast or occupy multiple locations. The economic impacts would be similar regardless of the exact location.

Following are specific assumptions and model inputs associated with the construction and operations phases for each of the three wave industry stages.

RESEARCH & DEVELOPMENT FACILITY COST ASSUMPTIONS

The analysis envisions a sizeable R&D facility on the Oregon coast, requiring 20,000 square feet of industrial space with supplementary office areas. As there is ample and inexpensive industrial space on the coast, we assume that the facility would lease already-existing space and make leasehold improvements as necessary.

The analysis also assumes that all expenditures to get the facility operating would occur in one year. Pre-opening expenses include direct labor costs for 25 full and part time employees, recruiting expenses, and office administration. As shown in Table 1, the total estimated cost to open the R&D facility would be $2 million.

[4] Hagerman, G., Bedard, R., and Previsic, M. "E21 EPRI survey and characterization of potential offshore wave energy sites in Oregon." EPRI. May 17, 2004.

Table 1: Cost to Open 20,000-Square Foot R&D Facility, 2008 $

Cost Category	Amount
Leasehold improvements to property	$600,000
Soft costs: contractor fees, permits, planning	$300,000
Pre-opening wages, recruitment & training	$500,000
Office equipment, computers, signage, and furniture	$100,000
Industrial equipment, scientific instruments	$500,000
Total cost to open	**$2,000,000**

Source: ECONorthwest; IMPLAN data.

All of the direct spending on construction labor for the R&D facility is assumed to occur within the coastal counties, as this project is expected to acquire local labor. However, other direct spending, such as fees paid to architects and engineers, is not confined to the coast, as some of this expertise may be outsourced to the more urban areas of the state. Overall, about $1.4 million in spending is expected to occur in the three coastal counties.

RESEARCH & DEVELOPMENT FACILITY OPERATING COST ASSUMPTIONS

The R&D facility would conduct a significant amount of research activity in addition to building and testing prototypes. Prototype testing would involve placing units in the ocean with total installed capacity up to several MW, which may result in modest amounts of salable electric power. Electricity sales, however, would be a minor byproduct of the research.

The main purpose of the R&D facility would be to advance the design and operating characteristics of wave energy systems and devices. Thus, for impact estimating purposes, this stage has an industry classification code of *physical sciences research facility,* and is not considered to be a power generating utility.

The facility's annual cash expenditures would be $6.8 million. Of that total, $3.6 million would be for direct labor expenses - the 40 employees of the facility - while $3.2 million would pay for goods and services. Direct labor expenses are shown in Table 2; goods and services costs are shown in Table 3.

Table 2: Annual Direct Labor Expenses of R&D Facility, 2008 $

Cost Category	Amount
Payroll wages	$2,985,220
Other employer costs	$632,251
- of which is payroll tax paid by employer	$252,251
- of which is health insurance and other cash benefits	$380,000
Total Cost	**$3,617,471**

Source: ECONorthwest; US Bureau of Labor Statistics' Wage and Occupational Survey.

The goods and services would be purchased from a wide variety of sectors, and a large portion of these expenses would be for the production of prototypes, such as purchases of parts and technical consulting. Rent expense is based on a value for industrial property in Reedsport and is comparable to rents elsewhere in the region.

Table 3: Annual Expenditures for Goods and Services for R&D Facility Operation, 2008 $

Sector	Dollars Spent
Wholesale purchases	$336,321
Technical consulting services	$335,749
Employment services	$252,372
Legal services	$142,114
Retail purchases	$112,107
Repair & maintenance	$104,676
Annual rent (excludes property tax & utilities)	$ 96,000
Other professional services	$ 92,381
Commercial and industrial equipment manufacturing	$82,659
Transport by water	$74,673
Advertising and related services	$70,924
Engineering services	$61,770
Monetary authorities	$61,483
Insurance agencies and brokerages	$60,935
Precision equipment repair and maintenance	$59,892
Engine equipment manufacturing	$50,000
Material handling equipment manufacturing	$50,000
General purpose machinery manufacturing	$50,000
Analytical laboratory instrument manufacturing	$50,000
All other sectors (includes property tax & utilities)	$1,085,087
Total	**$3,229,142**

Source: ECONorthwest; US Economic Census's physical sciences R&D facilities category; and IMPLAN data.

A significant amount of work will need to be completed before the wave energy industry can move from the R&D stage to the Commercial phase where a 500 MW wave farm can be constructed and operated at a competitive cost. This development will likely include progressively larger prototype installations in the 7 to 10 MW size and smaller-scale commercial installations of 100 MW or more. All of these intermediate stages will have their own economic impacts associated with them. For the economic analysis presented here, we have chosen a single commercial development stage (500 MW) as the focus of our analysis, with the understanding that there would be a significant amount wave energy industry activity prior to reaching this

goal. As discussed above, the 500 MW threshold is also one of OWET's stated goals for the Oregon wave energy industry.

Our cost assumptions for the 500 MW facility are discussed below.

500-MW Wave Farm Construction Cost Assumptions

Wave projects installed to date have been small and experimental. According to EnergyCurrent.com, a 4 MW wave power facility that has been approved for construction in Scotland would be the world's largest.[5] There are, however, plans for larger wave power facilities in Oregon, for instance by Ocean Power Technologies, Inc. (OPT). According to OPT's website, it has "filed applications for permits from the US Federal Energy Regulatory Commission for two 100-MW power generation projects located at Coos Bay and Newport, Oregon."[6] A 500 MW wave farm would therefore be very large, even by conventional energy standards. As a matter of comparison, Portland General Electric's largest plant is the 505 MW Beaver fossil fuel plant in Clatskanie, Oregon. [7]

In spite of all the wave energy work proceeding around the globe, research has not settled on a common design platform, which is necessary to minimize technological risks so that large-scale investment can begin in earnest. Given the circumstances, there is considerable uncertainty regarding what it would cost to build a 500 MW wave farm, what specific technology would be used, and how much labor would be necessary to commission and operate the project. For this analysis, we chose to build upon a recent estimate for a smaller, hypothetical commercial facility, and scale it up to a 500 MW facility.

In 2004, the Electric Power Research Institute estimated what it would cost to construct a 90 MW wave farm.[8] Our analysis scales the EPRI estimate up to 500 MW and accounts for inflation - using construction, producer price, and wage indices - to develop an estimate in 2008 dollars.[9] We then applied the learning curve cost reduction factors, described previously, to arrive at the costs listed in Table 4.

The estimated cost for constructing a 500 MW facility is about $750,000/MW, which is the cost needed to produce power at a comparable price to wind power in the future. This estimate may be conservative, however, as it does not take into account possible green power subsidies or

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[5] EnergyCurrent.com. "World's largest wave power project wins approval," posted January 23, 2009. Accessed February 10, 2009. http://www.energycurrent.com/index.php?id=3&storyid=15457

[6] Ocean Power Technologies, Inc. "Major Milestones." Accessed February 10, 2009. http://www.oceanpowertechnologies.com/major.htm

[7] Portland General Electric website, accessed February 10, 2009. http://www.portlandgeneral.com/about_pge/corporate_info/power_plants.aspx

[8] This analysis was based on floating "wave snake" energy conversion devices.

[9] We use the EPRI numbers as these are the only publicly available cost estimates that have enough detail to be used in the IMPLAN model. The EPRI numbers are also not linked to a specific wave energy company.

premium prices that wave power may be able to command. In the results section of this report, we explore several alternative scenarios that assume higher power costs for wave energy.

Table 4: Construction Costs for 500-MW Wave Farm, 2008 $

Cost Category	Amount
Equipment: Onshore transformers and grid	$8,283,500
Equipment: Cables	$6,130,000
Equipment: Mooring	$38,089,000
Equipment: Power conversion modules	$202,701,000
Concrete structures	$77,878,000
Building/facilities	$21,379,000
Installation work	$19,973,000
Total	**$374,433,500**

Source: ECONorthwest analysis of EPRI data.

The analysis assumes that the electric components and cables, power modules, structures, and other capital goods are bought primarily from supplier firms, which is common practice in the highly specialized world of power plant development. Table 5 shows the percentage of expenditures, by industry sector, which would likely go to coastal supplier firms in the near future, based on the current industrial composition of Oregon's economy. Note that none of the power conversion module or electrical cable/component manufacturing is envisioned to occur along the coast for this development stage. Those expenditures that were not allocated to coastal firms were allocated to firms elsewhere in Oregon so that all construction spending is expected to occur within the state.

Table 5: Percent of Construction Expenditures to Coastal Firms

Industry Sector	Percent Supplied by Coastal Firms
Structures construction	100%
Concrete products manufacturing*	35%
Platework and fabricated structures manufacturing	10%
Power distribution and specialty transformer manufacturing	0%
Energy wire and cable manufacturing	0%
Other electrical equipment and component manufacturing	0%
Water transportation	100%
Architectural and engineering services	50%
Installation labor	100%

** Most raw ingredients (cement, crushed rock, sand and forms) would be produced elsewhere in Oregon and mixed/assembled on-site*

Source: ECONorthwest

For the impact analysis, we assumed that the project would be constructed in one year. Based on the preceding cost assumptions, we assume that the project would directly fund the equivalent of 361 full-time jobs, which are shown in Table 6.

Table 6: Full-Time Equivalent Jobs Directly Related to Wave Farm Construction, 2008 $

Payroll Category	Jobs	Payroll and Benefits Per Employee
Labor, engineering & planning	83	$66,080
Labor, installation	278	$44,190

Source: ECONorthwest analysis of EPRI and BLS data. Does not include those working for suppliers and contractors.

500-MW Wave Farm Operating Cost Assumptions

Table 7 shows the estimated annual costs of operating a 500-MW wave farm on the Oregon coast. These figures are based upon estimates developed by EPRI, which were then adjusted for inflation, facility size, and the aforementioned learning factor. Our analysis also adds $5 million per year for administrative labor and overhead costs, which were absent from the EPRI estimates.

EPRI's estimates included the cost of a major equipment overhaul every ten years. Our analysis disaggregates wave farm overhaul costs into an annual amount for a typical year, which is equal to one-tenth of the total overhaul cost. This is done to capture the impacts of regular but episodic capital outlays.

Table 7: Wave Farm Annual Operations Costs, 2008 $

Cost Category	Cost
Annualized portion of overhaul (one-tenth of ten-year overhaul)	
Parts	$2,530,619
Labor	$1,719,790
Costs that occur every year	
Administrative labor	$2,189,732
Overhead expenses	$2,810,268
Operations and Maintenance labor	$4,092,400
Insurance	$7,571,343
Parts & supplies	$7,891,794
Total Annualized Costs	**$28,805,945**

Source: ECONorthwest analysis of EPRI.

Our analysis estimates that the large-scale wave farm would require the equivalent of 81 full-time employees in normal operating years and an additional 299 full-time equivalent workers every tenth year when overhauls are conducted. Thus, on average, direct employment at the power generation facility would be 111.

With a 30 percent capacity factor, the wave energy farm would generate 1,314,000 MWh of renewable electric energy per year. Assuming an avoided cost of $63 a MW, the value of the annual output would be about $82.8 million.

WAVE ENERGY INDUSTRIAL PHASE CONSTRUCTION COST ASSUMPTIONS

This development stage assumes that after wave energy is shown to be a proven and commercially competitive power generation technology, Oregon would become a global player in the provision of wave energy equipment and engineering services. A cluster of manufacturers and service companies would therefore develop on the coast.

For purposes of this analysis, we have assumed that in a typical year the Oregon-based wave energy cluster would produce the equipment and services necessary to install 2,500 MW of capacity elsewhere around the world. Some of these goods and services would come from Oregon, while others would not. For instance, it is not likely that Oregon would be a major producer of cables and concrete structures (other states and countries already have strong advantages), and we assumed that 75 percent of the transformers and grid equipment would be produced out of state. By definition, the construction of facility buildings for new wave farms, and the installation work, would also occur outside the state.

We estimate that the Oregon wave energy cluster would require almost 1,325,000 square feet of industrial and office space, and Table 8 shows the cost of building and outfitting this space would be about $626 million. Note that the industries involved in developing this stage are capital intensive. Therefore, most of the spending on the cluster's capacity would be for equipment, installation, and soft costs, and not for direct building construction. Furthermore, most of the expenditures for equipment would occur outside of the local, coastal economy, where only about $200 million would be spent. The remaining spending would largely occur elsewhere in Oregon, while about 15 percent would "leak" to other national and international firms.

Based on conversations with industry experts, the construction period for building a 500 MW facility would likely range from 5 to 10 years.

Table 8: Cost of Construction for Wave Energy Cluster Facilities, 2008 $

Facilities Component	SF	$/SF	Cost
Industrial building construction	1,256,000	$84	$105,919,736
Commercial building construction	68,745	$148	$10,191,589
Equipment, installation & soft costs	-	$385	$509,537,051
Total	**1,324,745**	**$472**	**$625,648,377**

Source: ECONorthwest analysis of data from McDermott International and FW Dodge.

These estimates are based in part on McDermott International's 10-K report and earlier reports from Babcock & Wilcox, which was acquired by McDermott.[10] These data were used to estimate the industrial space needed per unit of output as well as the amount of capital equipment that would be needed. Industrial and office building costs were obtained from actual statewide averages for Oregon from FW Dodge Construction.

WAVE ENERGY INDUSTRIAL PHASE OPERATING COST ASSUMPTIONS

This final stage of development assumes that Oregon's wave energy industrial cluster would leverage its expertise to sell 2,500 MW of power generation capacity around the world. Presumably, the industry may also supply wave farms in the state occasionally, however, these activities and spending are not considered here. Instead, only the tradable portions of the industry (i.e., the 2,500 MW that is exported to other states and countries) are tabulated.[11]

As shown in Table 9, the vast majority of spending for of this cluster would be for manufacturing the power generation modules. This sector would have an annual output over a billion dollars

[10] These firms produce power plan equipment and also do platework.

[11] As noted before, some of the costs of developing wave energy farms would not accrue to the Oregon cluster because some work would more logically occur where the construction takes place. Thus, the economic output of the Oregon *cluster* is valued at $511,778 per MW of delivered capacity, which is less than the $748,867 per MW for the 500 MW development in Oregon (from Table 4), when relatively more goods and services are produced in state.

and employ 3,676 workers with annual wages and benefits of $61,193 each. Importantly, in this long-term scenario we have assumed that the Oregon industry has progressed to the point where all or much of Oregon's wave energy output (for export) could be provided by central coast firms (i.e., new firms have started up, and/or existing firms elsewhere in the state have opened operations along the coast). This is a speculative but achievable assumption, given the strong industrial base of cities such as Reedsport, North Bend and Coos Bay, for instance.

Table 9: Annual Output & Employment of Potential Industry Cluster in Oregon, 2008 $

Industry	Percent from Oregon	Output on Oregon Coast	Employees	Payroll & Benefits Per Employee
Manufacturing: power distribution & transformer equip.	25%	$10,354,375	38	$53,711
Engineering services	100%	$65,140,158	344	$85,849
Manufacturing: platework & structural steel	100%	$190,445,000	1,001	$54,713
Manufacturing of wave power generation modules	100%	$1,013,505,000	3,676	$61,193
Total		**$1,279,444,533**	**5,058**	**$61,529**

Source: ECONorthwest analysis of EPRI, industry reports, and BLS data.

The preceding discussion focuses on the spending assumptions that were used as inputs to the IMPLAN model. The following section presents the IMPLAN results showing the estimated economic impacts resulting from this spending for each of the three wave energy industry stages.

4. ECONOMIC IMPACT RESULTS

SUMMARY

The various cost assumptions discussed in the previous section were used as inputs to estimate the economic impacts of the three proposed stages of wave energy industry development. As described in Section 2, we use the IMPLAN model to determine the economic contributions of these wave projects to the Oregon Coast economy (i.e., within Lincoln, Douglas, and Coos counties) and to the Oregon economy overall. This section of the report presents the IMPLAN results, allocated to three types of economic impacts: direct impacts, indirect impacts, and induced impacts.

Table 10 and Table 11 summarize the total economic and fiscal impacts of the construction and operations of the three wave industry stages in the state of Oregon. The impacts of the construction phase and the operations phase should be considered separately and cannot be added together. The total impacts displayed in these summary tables are the sum of the direct, indirect, and induced impacts. The total economic impacts for the three coastal counties are presented at the top of the tables and the economic impacts for the state overall are at the bottom. For the 500 MW facility, the construction period is estimated to be 5 to 10 years. Consequently, the construction economic impacts shown in Table 10 for the commercial phase would accrue over a 5-10 year period.

As shown in Table 10, construction during the R&D phase is estimated to create 45 jobs in Oregon's coastal communities. The construction job impacts increase to 802 jobs in the commercial phase and 2,700 in the industrial phase. Similarly, economic output for Oregon's coastal communities is estimated at over $2 million in the R&D stage and eventually increases to over $300 million in the industrial wave cluster stage. Tax revenues to the coastal area are also expected to be substantial, eventually increasing to almost $14 million in the industrial stage. These impacts will persist only for the duration of the construction period in each phase.

Larger economic impacts are estimated for the entire state as additional resources will be employed from other non-coastal parts of Oregon. Statewide employment impacts are expected to increase from 48 in the R&D phase to over 6,000 in the industrial stage. The wave energy industry could also potentially increase state tax revenues by $42 million should the wave energy industry mature to the industrial stage. Again, these impacts occur only during the 5-10 year construction phase.

Table 10: Total Economic Impacts of Construction

Type of Impact	R&D Stage Total Impacts	Commercial Stage Total Impacts	Industrial Stage Total Impacts
Coast Only			
Output	**$2,116,677**	**$100,146,845**	**$306,594,484**
Total Value Added	**$1,309,716**	**$48,136,457**	**$157,156,074**
• Wages	$991,065	$32,136,598	$89,953,110
• Business Income	$124,195	$4,596,643	$22,777,283
• Other Income	$147,768	$9,200,002	$36,076,201
• Production business taxes	$46,688	$2,203,214	$8,349,480
Jobs	**45**	**802**	**2,700**
Total State and Local Taxes and Fees	**$77,482**	**$3,694,965**	**$13,970,695**
Oregon Total			
Output	**$2,732,900**	**$680,010,413**	**$888,800,509**
Total Value Added	**$1,638,200**	**$277,396,697**	**$426,687,809**
• Wages	$1,200,900	$191,923,404	$260,600,612
• Business Income	$140,900	$14,672,951	$35,076,959
• Other Income	$223,400	$53,300,015	$101,882,833
• Production business taxes	$73,000	$17,500,327	$29,127,405
Jobs	**48**	**4,089**	**6,032**
Total State and Local Taxes and Fees	**$114,200**	**$26,090,317**	**$42,014,068**

Source: ECONorthwest IMPLAN results.

Additional economic impacts will occur from the sustained operations of the wave energy facility, as shown in Table 11 for each industry stage. Unlike the construction impacts, the operations impacts will occur annually for as long as the facility is operated.

At the mature industrial stage, the wave energy industry could sustain over 11,000 jobs along Oregon's coast and over 13,000 jobs statewide. The industrial phase would also increase economic output along the coast by almost $2 billion annually and $2.4 billion statewide. This phase would also provide new tax revenue of over $56 million to Oregon's coast communities and over $90 million to the entire state.

Table 11: Total Annual Economic Impacts of Operations

Type of Impact	R&D Stage Total Impacts	Commercial Stage Total Impacts	Industrial Stage Total Impacts
Coast Only			
Output	**$11,346,653**	**$47,255,101**	**$1,936,007,634**
Total Value Added	**$6,189,223**	**$16,602,041**	**$670,541,557**
• Wages	$4,999,163	$13,284,243	$512,414,213
• Business Income	$282,687	$641,207	$30,821,962
• Other Income	$677,135	$2,047,037	$90,824,303
• Production business taxes	$230,238	$629,554	$36,481,079
Jobs	**91**	**264**	**11,113**
Total State and Local Taxes and Fees	**$419,103**	**$1,205,710**	**$56,476,803**
Oregon Total			
Output	**$13,455,140**	**$57,303,236**	**$2,413,274,917**
Total Value Added	**$7,415,664**	**$21,988,722**	**$926,462,844**
• Wages	$5,769,837	$16,574,775	$673,171,833
• Business Income	$331,024	$891,259	$38,834,973
• Other Income	$979,063	$3,377,955	$152,011,309
• Production business taxes	$335,740	$1,144,733	$62,444,729
Jobs	**100**	**316**	**13,630**
Total State and Local Taxes and Fees	**$552,529**	**$1,844,176**	**$90,096,184**

Source: ECONorthwest IMPLAN results.

A more detailed examination of the various types of economic impacts for each wave industry stage is presented in the remainder of this section. Each industry development stage consists of two phases, the construction phase and the operations phase, and each are described separately:

1. Establishment of an R&D facility in a rented industrial building.
2. Operation of the R&D facility when fully functioning.
3. Construction of a 500 MW commercial wave energy farm.
4. Operation of a 500 MW wave energy farm when fully functioning.
5. Construction for a wave energy equipment and services cluster (industrial phase).
6. Operation of a mature wave energy equipment and services cluster (industrial phase).

R&D Facility Construction

Table 12 shows the economic impacts of the construction phase of the R&D facility in a rented, existing industrial building. The top part of table describes the economic impacts on the Oregon Coast, while the bottom displays the total impacts across the state (including the coast). The majority of the spending is modeled to take place on the coast, as construction labor is assumed to be acquired locally. Consequently, nearly all of the economic impacts are captured by the local economy. The construction of the R&D facility is expected to foster $2.1 million in economic output for the coastal economy, including nearly $1 million in wages and 45 jobs. In the state overall, the construction project should produce $2.7 million in economic output, including $1.2 million in wages and 48 jobs. Note that the jobs created persist only for the length of the construction phase.

Table 12 also displays the fiscal impacts of building the R&D facility for the Oregon economy. The construction project is expected to generate $77,000 in taxes for the local coastal economy and $114,000 for the state overall.

Table 12: Economic Impacts of R&D Facility Construction

Type of Impact	Direct	Indirect	Induced	Total
Coast Only				
Output	**$1,392,810**	**$237,226**	**$486,641**	**$2,116,677**
Total Value Added	**$887,246**	**$125,973**	**$296,497**	**$1,309,716**
• Wages	$773,426	$65,770	$151,869	$991,065
• Business Income	$81,506	$19,958	$22,731	$124,195
• Other Income	$26,059	$29,185	$92,524	$147,768
• Production business taxes	$6,255	$11,060	$29,373	$46,688
Jobs	**38**	**2**	**6**	**45**
Total State and Local Taxes and Fees		**$77,482**		
Oregon Total				
Output	**$1,525,800**	**$399,100**	**$808,000**	**$2,732,900**
Total Value Added	**$945,900**	**$214,200**	**$478,100**	**$1,638,200**
• Wages	$822,500	$120,000	$258,400	$1,200,900
• Business Income	$86,300	$25,000	$29,600	$140,900
• Other Income	$29,100	$51,400	$142,900	$223,400
• Production business taxes	$8,000	$17,800	$47,200	$73,000
Jobs	**38**	**3**	**8**	**48**
Total State and Local Taxes and Fees		**$114,200**		

Source: ECONorthwest IMPLAN results.

R&D Facility Operations

Table 13 shows the estimated economic impacts of the operations phase of the fully functioning R&D facility on the Oregon Coast. The impacts represent one year of facility operations. By definition, all R&D operations activities occur onsite, and as a result, the direct economic impacts for the state of Oregon equal the direct economic impacts on the coast. However, the indirect and induced impacts for the state are somewhat larger than the coast, as spending by businesses and households leaks out of the local economy and is captured by businesses elsewhere in Oregon.

Operations of the R&D facility for a typical year are expected to contribute a total of $11 million in economic output to the coastal economy and $13 million to the state overall. The operations activities will create about 91 jobs on the coast and an additional nine jobs in other areas of the state, for a total of 100 Oregon jobs. Moreover, R&D operations will contribute approximately $419,000 in state and local taxes to the coastal economy and $553,000 to the state overall.

Table 13: Annual Economic Impacts of R&D Facility Operations

Type of Impact	Direct	Indirect	Induced	Total
Coast				
Output	**$6,846,614**	**$2,212,079**	**$2,287,960**	**$11,346,653**
Total Value Added	**$3,617,471**	**$1,192,355**	**$1,379,397**	**$6,189,223**
• Wages	$3,617,471	$688,052	$693,640	$4,999,163
• Business Income	$0	$176,450	$106,237	$282,687
• Other Income	$0	$232,906	$444,229	$677,135
• Production business taxes	$0	$94,947	$135,291	$230,238
Jobs	**40**	**25**	**25**	**91**
Total State and Local Taxes and Fees		**$419,103**		
Oregon Total				
Output	**$6,846,614**	**$2,949,782**	**$3,658,744**	**$13,455,140**
Total Value Added	**$3,617,471**	**$1,649,074**	**$2,149,119**	**$7,415,664**
• Wages	$3,617,471	$1,003,934	$1,148,432	$5,769,837
• Business Income	$0	$196,507	$134,517	$331,024
• Other Income	$0	$325,139	$653,924	$979,063
• Production business taxes	$0	$123,494	$212,246	$335,740
Jobs	**40**	**27**	**33**	**100**
Total State and Local Taxes and Fees		**$552,529**		

Source: ECONorthwest IMPLAN results.

Commercial Wave Farm Construction (500 MW)

The second stage of envisioned wave industry development is to build and operate a 500 MW commercial wave farm off the Oregon Coast. The construction phase of this project is expected to generate $100 million of economic output for the coast, including $32 million in wages and 802 local jobs for the duration of the construction phase (5-10 years).

The direct coastal impacts are significantly smaller than the direct state impacts, as many of the direct construction inputs are assumed to be purchased from firms beyond the local coastal economy (see Table 5). Similarly, the indirect and induced impacts for the state are much larger than those captured by the coast, as the affected statewide businesses and households make purchase goods and services from businesses in other areas of the state.

The total economic impact of the construction phase of the 500 MW wave farm for Oregon is $680 million in economic output, $192 million in wages, and 4,089 jobs. The total fiscal impact on Oregon is $26 million in state and local taxes.

Table 14: Economic Impacts of Commercial Wave Farm Construction (500 MW)

Type of Impact	Direct	Indirect	Induced	Total
Coast				
Output	**$68,855,033**	**$15,722,642**	**$15,569,170**	**$100,146,845**
Total Value Added	**$29,971,211**	**$8,463,148**	**$9,702,098**	**$48,136,457**
• Wages	$22,358,998	$4,605,410	$5,172,190	$32,136,598
• Business Income	$2,647,764	$1,226,346	$722,533	$4,596,643
• Other Income	$4,215717	$2,118,203	$2,866,082	$9,200,002
• Production business taxes	$748,732	$513,189	$941,293	$2,203,214
Jobs	**464**	**154**	**185**	**802**
Total State and Local Taxes and Fees		**$3,694,965**		
Oregon Total				
Output	**$374,433,499**	**$184,775,538**	**$120,801,376**	**$680,010,413**
Total Value Added	**$111,780,095**	**$92,678,779**	**$72,937,823**	**$277,396,697**
• Wages	$94,074,472	$57,014,314	$40,834,618	$191,923,404
• Business Income	$3,497,623	$6,899,549	$4,275,779	$14,672,951
• Other Income	$10,834,765	$21,563,008	$20,902,242	$53,300,015
• Production business taxes	$3,373,235	$7,201,908	$6,925,184	$17,500,327
Jobs	**1,719**	**1,192**	**1,177**	**4,089**
Total State and Local Taxes and Fees		**$26,090,317**		

Source: ECONorthwest IMPLAN results.

As discussed earlier, the construction costs assumed for this analysis are about $750,000/MW for wave energy, which is consistent with the estimated cost needed to be competitive with wind energy in the future. To test this assumption, we have also provided altnernative cost scenarios where wave energy construction costs for a 500 MW facility is assumed to $1,000,000/MW and $1,500,000/MW.

The results of these alternative scenarios are presented in Table 15. The estimated economic impacts all increase linearly relative to the assumed increases in costs, with an increase in all economic impacts of 33 percent at an assumed cost $1,000,000/MW and 100 percent at $1,500,0000/MW.

Table 15: Alternative Construction Cost Scenarios

Type of Impact	Construction Cost = $750,000/MW	Construction Cost = $1,000,000/MW	Construction Cost = $1,500,000/MW
Output	**$100,146,845**	**$133,195,304**	**$200,293,690**
Total Value Added	**$48,136,457**	**$64,021,488**	**$96,272,914**
• Wages	$32,136,598	$42,741,675	$64,273,196
• Business Income	$4,596,643	$6,113,535	$9,193,286
• Other Income	$9,200,002	$12,236,003	$18,400,004
• Production business taxes	$2,203,214	$2,930,275	$4,406,428
Jobs	**802**	**1,067**	**1,604**
Total State and Local Taxes and Fees	**$3,694,965**	**$4,914,303**	**$7,389,930**
Output	**$680,010,413**	**$904,413,849**	**$1,360,020,826**
Total Value Added	**$277,396,697**	**$368,937,607**	**$554,793,394**
• Wages	$191,923,404	$255,258,127	$383,846,808
• Business Income	$14,672,951	$19,515,025	$29,345,902
• Other Income	$53,300,015	$70,889,020	$106,600,030
• Production business taxes	$17,500,327	$23,275,435	$35,000,654
Jobs	**4,089**	**5,438**	**8,178**
Total State and Local Taxes and Fees	**$26,090,317**	**$34,700,122**	**$52,180,634**

Commercial Wave Farm Operations (500 MW)

Table 16 shows the economic impacts resulting from one year of wave farm operations. All operations activities are expected to utilize local goods and services, and thus, the direct economic impacts for the coast are equal to the direct impacts for the state.

However, due to indirect and induced spending captured by other areas of the state, the total economic impacts for Oregon State are higher than those absorbed on the coast. The total impacts for the coast are an estimated $47 million in economic output, $13 million in wages, 264 local jobs, and over $1 million in taxes and fees. In Oregon State, the total economic impact is expected to be $57 million in economic output, $17 million in wages, and a total of about 316 jobs should be created. The fiscal impact is nearly $2 million annually.

Table 16: Annual Economic Impacts of Wave Farm Operations (500 MW)

Type of Impact	Direct	Indirect	Induced	Total
Coast				
Output	**$28,805,945**	**$12,406,199**	**$6,042,957**	**$47,255,101**
Total Value Added	**$8,001,922**	**$4,939,770**	**$3,660,349**	**$16,602,041**
• Wages	$8,001,922	$3,425,835	$1,856,486	$13,284,243
• Business Income	$0	$360,487	$280,720	$641,207
• Other Income	$0	$882,993	$1,164,044	$2,047,037
• Production business taxes	$0	$270,455	$359,099	$629,554
Jobs	**111**	**85**	**68**	**264**
Total State and Local Taxes and Fees		**$1,205,710**		
Oregon Total				
Output	**$28,805,945**	**$18,039,257**	**$10,458,034**	**$57,303,236**
Total Value Added	**$8,001,922**	**$7,796,613**	**$6,190,187**	**$21,988,722**
• Wages	$8,001,922	$5,222,021	$3,350,832	$16,574,775
• Business Income	$0	$509,668	$381,591	$891,259
• Other Income	$0	$1,523,947	$1,854,008	$3,377,955
• Production business taxes	$0	$540,977	$603,756	$1,144,733
Jobs	**111**	**108**	**97**	**316**
Total State and Local Taxes and Fees		**$1,844,176**		

Source: ECONorthwest IMPLAN results.

Wave Cluster Construction

The final stage of industry development is the wave industrial cluster that provides energy equipment and expertise to the international market. The total project costs necessary to build and outfit the facilities is estimated to be $625.7 million. We assume that the inputs for constructing the buildings will be found locally. Much of the remaining construction costs will go toward developing the wave cluster's capacity, including spending on equipment, installation, and soft costs. The majority of these costs are expected to be outsourced to other areas of Oregon, other states, as well as internationally.

Table 17 shows the expected economic contributions due to the construction phase of the wave cluster, both to the coastal economy and to Oregon State overall. The construction of the wave cluster infrastructure is expected to create $889 million in economic output for the state of Oregon, and $307 million of this is captured by the coastal economies. The construction activities should create a total of 6,032 jobs (persisting for the length of the construction

timeline) and 2,700 of these are on the coast. The construction should also raise $14 million in taxes for the coast and $42 million for Oregon overall.

Table 17: Economic Impacts of Wave Cluster Construction

Type of Impact	Direct	Indirect	Induced	Total
Coast				
Output	**$208,897,994**	**$44,195,111**	**$53,501,379**	**$306,594,484**
Total Value Added	**$99,858,639**	**$23,841,009**	**$33,456,426**	**$157,156,074**
• Wages	$58,942,454	$13,045,016	$17,965,640	$89,953,110
• Business Income	$17,165,531	$3,153,789	$2,457,963	$22,777,283
• Other Income	$20,217,400	$6,038,418	$9,820,383	$36,076,201
• Production business taxes	$3,533,254	$1,603,786	$3,212,440	$8,349,480
Jobs	**1,640**	**422**	**638**	**2,700**
Total State and Local Taxes and Fees		**$13,970,695**		
Oregon Total				
Output	**$531,773,647**	**$182,292,649**	**$174,734,213**	**$888,800,509**
Total Value Added	**$222,304,584**	**$98,360,740**	**$106,022,485**	**$426,687,809**
• Wages	$144,277,432	$56,587,724	$59,735,456	$260,600,612
• Business Income	$20,116,927	$8,742,037	$6,217,995	$35,076,959
• Other Income	$46,876,471	$24,874,775	$30,131,587	$101,882,833
• Production business taxes	$11,033,754	$8,156,204	$9,937,447	$29,127,405
Jobs	**3,011**	**1,307**	**1,714**	**6,032**
Total State and Local Taxes and Fees		**$42,014,068**		

Source: ECONorthwest IMPLAN results.

Wave Energy Industrial Operations

Table 18 shows the estimated economic impacts resulting from one year of operating a mature wave energy cluster. Our model assumes that in one year the Oregon-based cluster would produce the equipment and services necessary to install 2,500 MW of capacity elsewhere around the world. Therefore, some of the costs involved would logically take place at construction sites in other states or countries. However, for all the operations activities that would take place in Oregon, our model assumes that they will occur locally on coast. Thus, the direct impacts for the coast are equal to the direct economic impacts for Oregon State. In addition to general operations and maintenance jobs, examples of direct operations activities include engineering services, manufacturing power distribution equipment, manufacturing platework and steel, and manufacturing wave power generation modules.

However, the direct impacts on the coast create indirect and induced impacts in other areas of Oregon. As a result, the total economic impacts in Oregon overall are higher than those confined to the coast. The total economic output derived from the cluster's operations in Oregon are estimated to be $2.4 billion, including $673 million in wages and over 13,630 new jobs. In addition, operations are estimated to create $90 million in state and local taxes.

Table 18: Annual Economic Impacts of Wave Cluster Operations

Type of Impact	Direct	Indirect	Induced	Total
Coast				
Output	**$1,279,444,532**	**$438,875,542**	**$217,687,560**	**$1,936,007,634**
Total Value Added	**$322,238,136**	**$212,025,141**	**$136,278,280**	**$670,541,557**
• Wages	$311,247,936	$127,836,526	$73,329,751	$512,414,213
• Business Income	$0	$20,840,663	$9,981,299	$30,821,962
• Other Income	$0	$50,901,249	$39,923,054	$90,824,303
• Production business taxes	$10,990,200	$12,446,703	$13,044,176	$36,481,079
Jobs	**5,059**	**3,455**	**2,599**	**11,113**
Total State and Local Taxes and Fees		**$56,476,803**		
Oregon Total				
Output	**$1,279,444,532**	**$717,094,112**	**$416,736,273**	**$2,413,274,917**
Total Value Added	**$322,238,136**	**$352,317,056**	**$251,907,652**	**$926,462,844**
• Wages	$311,247,936	$220,552,388	$141,371,509	$673,171,833
• Business Income	$0	$24,184,217	$14,650,756	$38,834,973
• Other Income	$0	$79,963,873	$72,047,436	$152,011,309
• Production business taxes	$10,990,200	$27,616,578	$23,837,951	$62,444,729
Jobs	**5,059**	**4,505**	**4,066**	**13,630**
Total State and Local Taxes and Fees		**$90,096,184**		

Source: ECONorthwest IMPLAN results.

5. ECONOMIC CONTRIBUTIONS OF THE FISHING INDUSTRY

In order that the wave energy economic impacts be considered in context with existing ocean uses, this section of the report presents the economic contributions of Oregon's commercial and recreational fishing industries. The Oregon Department of Fish and Wildlife (ODFW) produces a biennial study entitled "Oregon's Commercial Fishing Industry," which estimates the economic contribution of the commercial fishing industry on the entire Oregon Coast, and the most recent publication covers the years 2005 and 2006.[12] The study is authored by fishery economists at The Research Group, located in Corvallis, Oregon, and the results of this study are summarized in this section.[13]

Note that in recent years the fishing industry in Oregon has continued to be depressed due to lower fish stocks and in some cases the closing of entire salmon fishing seasons. The current economic downtown will also have a negative impact on Oregon fishing. Although the 2006 data are the latest we have to work with, it is likely that current economic activity from commercial fishing in Oregon is now lower than the numbers reported here.

Estimating the potential economic impacts of wave energy on Oregon's fishing industry is outside the scope of this current study. There is considerable interest and concern regarding these impacts among the various stakeholder groups we interviewed, however. Additional research is currently being conducted on the potential biological and environmental impacts of wave energy, and this research needs to be completed prior to estimating the potential economic impacts of wave energy on the fishing industry.

Oregon's commercial fishing industry is comprised of several occupations, including vessel owners, captains, crews, workers at seafood processing plants, and suppliers for fishing industry businesses. The economic contribution of the Oregon commercial fishing industry includes both proprietary income and wages earned by this group, as well as the re-spending of these earnings throughout the Oregon economy.

The spending and re-spending of revenues from local harvesters, processors, and distant water harvesters creates additional wages and profits for workers and business owners in the general Oregon economy. The Research Group has developed a unique input-output model called FEAM (Fisheries Economic Assessment Model) in order to estimate the flow of dollars from harvesting, processing, and distributing seafood products within and among industries and arriving at Oregon households.[14] The sum of all of these dollar streams is referred to as total personal income, or the total economic contribution.

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[12] "Oregon's Commercial Fishing Industry Year 2005 and 2006 Review and Year 2007 Outlook." Oregon Department of Fish and Wildlife and Oregon Coastal Zone Management Association. June 2007.

[13] The original scope of work for this report had ECONorthwest using IMPLAN to estimate the economics of impacts of Oregon's fishing industry. However, as research progressed it became apparent that this would be duplicating the current work of The Research Group, which is in the process up of updating their economic study on Oregon fisheries. Rather than duplicate efforts, we decided to rely on existing secondary research to provide the fisheries context for this report.

[14] The FEAM calculates economic contributions using response coefficients based on revenue flows and expenditure

As shown in Table 19, the Research Group estimated a total of $421 million in economic contributions from the commercial fishing industry in 2006, which is higher than all previous years and four percent higher than 2005. This record high $421 million economic impact in 2006 is primarily the result of higher crab landings, the sardine fishery, and a large supply of Pacific whiting.

In 2006, the $421 million represented about eight percent of income earned on the coast (and less than one percent of income earned in all of Oregon). This figure also translates to about 14,000 full-time jobs, each paying $30,000.

Table 19: Commercial Fishing Economic Contribution, 2000 - 2006

Year	Annual Economic Contribution (Personal Income, $ Millions)
2006	$421.2
2005	$403.8
2004	$413.6
2003	$383.7
2002	$335.5
2001	$327.9
2000	$341.8

Source: The Research Group

As shown in Table 20, 61 percent ($259 million) of the total impact of the commercial fishing industry on the Oregon economy is derived from fish landings. Crab landings contributed $98 million in personal income, sardines produced $50 million, groundfish resulted in $38 million, and Pacific whiting supplied $37 million. Tuna, shrimp, salmon, Pacific halibut and other fish landings contributed a total of $36 million in personal income to the Oregon economy.

The remaining 39 percent ($162 million) of the total economic contribution is attributed to the distant water fleet.[15] The distant water fleet makes landings to at-sea processors and onshore processors in other West Coast states, Alaska, the southern Pacific Ocean, and elsewhere.

Earned income from the salmon species was lower in 2006 than other recent years (but still higher than the 1990s) due to decreased landings, although this was offset somewhat by higher market prices. Lower salmon landings are in part the result of five years of drought conditions that dramatically lowered salmon populations in the Klamath Basin.[16] However, to mitigate the

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categories of harvesters and processors. A fleet classification scheme is central to the development of the FEAM where effort, revenues and expenditures are tracked by types of commercial fishing vessels.

[15] The Research Group extracted landing data from the Pacific Coast Fisheries Information Network (PacFin).

[16] U.S. Department of Commerce Press Release, 2006: http://www.commerce.gov/opa/press/Secretary_Gutierrez/2006_Releases/August/10_KlamathDisaster_Release.htm

impacts of this fishery failure, the Oregon salmon industry was supported by government subsidies in 2006. The economic contribution of the shrimp industry was also lower in 2006 than the previous year and garnered lower market prices.

Geographically, the major ports contributing to economic impacts on the Oregon Coast in 2006 are Newport and Astoria. These two ports also collect significant revenues from distant water fisheries, which are returned to their local economies. Including landed fish and income generated by the distant water fleet, Newport contributed about $123 million to its local economy and Astoria contributed about $119 million to its local economy. Along the entire Oregon Coast, the commercial fishing industry produced a total of $298 million in personal income for local communities in 2006.

The Oregon commercial fishing sector is becoming increasingly industrialized, with larger boats focusing on high-volume but lower-value fish species. For example, in 2006, Pacific whiting represented 71 percent of the landed volume but only 12 percent of the landed value. The ports of Newport and Astoria, with high-volume processing capabilities, reap the benefits of this trend.

Table 20: Economic Impacts of the Oregon Commercial Fishing Industry (2006)

	Economic Contribution 2006 (Personal Income)
Fish Landings	**$259 million**
• *Dungeness Crab*	*$98 million*
• *Sardine*	*$50 million*
• *Groundfish*	*$38 million*
• *Pacific whiting*	*$37 million*
• *Tuna*	*$14 million*
• *Shrimp*	*$10 million*
• *Salmon*	*$8 million*
• *Pacific halibut*	*$1 million*
• *All other fish*	*$3 million*
Distant Water Fleet	**$162 million**
Total	**$421 million**

Source: The Research Group

The Recreational Fishing Industry

In addition to the commercial fishing industry, recreational fishing on the Oregon Coast generates substantial economic impacts. Oregon had 150,000 recreational saltwater anglers (age 16 and older) in 2006. This group stimulates economic activity as a result of expenditures on travel, equipment, supplies, fishing license sales, as well as federal excise taxes and import duties on fishing gear.

The most recent Sportfishing in America report published by the American Sportfishing Association analyzed the economic impacts of recreational fishing in Oregon in 2006, and the results of this report are presented in Table 21.[17] This study utilized the standard IMPLAN economic modeling tool in order to model revenue generated by recreational saltwater fishing in Oregon, as well as the multiplier effect in the Oregon economy.

Table 21: Economic Impact of Recreational Fishing on Oregon Coast (2006)

Type of Impact	Economic Impact
Retail sales	$153,712,985
Multiplier effect	$250,235,372
Salaries, wages, and business earnings	$76,485,153
Federal tax revenues	$18,146,340
State and local tax revenues	$16,690,966
Jobs	2,488

Source: Sportfishing in America

[17] "Sportfishing in America: An Economic Engine and Conservation Powerhouse." American Sportfishing Association. January 2008.

6. ISSUES RAISED BY STAKEHOLDERS

In the process of conducting interviews with stakeholders for this study, a variety of issues and concerns were raised outside those that related directly to the economic impact modeling. These stakeholder comments relate to market and infrastructure issues that should be addressed in order for the wave energy industry to develop and begin producing economic benefits to Oregon while at the same time minimizing any adverse affects on other industries. Key considerations for policymakers raised by stakeholders include the following:

- **Develop an expeditious permitting process for small wave energy projects.** Currently, the industry has a high potential for smaller entrepreneurial firms to develop prototypes that warrant testing in real-world conditions. So that these smaller, less-capitalized firms can participate to help grow the industry, the project approvals process should be made to operate as quickly, transparently and inexpensively as possible.

- **Support industry-supportive college and high school education programs so that wave energy companies have access to relevant research skills and qualified workers.** In particular, skilled workers will be needed in the fields of mechanical and electrical engineering, electrical component design and manufacturing, platework and fabricated metal structures, and advanced concrete product manufacturing. These training programs could be coordinated to also supplement the needs of the wind, solar, and/or geothermal energy industries where there is an overlap of required skill sets.

- **Train fishing workers to work in the wave energy industry, perhaps as wave park maintenance and operations staff.** This would expand the range of employment opportunities to the fishing industry, particularly if future wave energy jobs earn higher and/or steadier incomes than fisheries work. This strategy should be pursued even if wave energy and fishing work are found to be compatible in the same areas, as some fisheries are at risk of episodic closures for stock maintenance reasons.

- **Seek to configure wave parks in ways that maximize fisheries yield.** This would be especially true if marine reserves (i.e. no-fishing zones) are determined to be necessary to protect wave energy equipment. For instance, it may be economically feasible to configure wave equipment/fishing reserves in smaller areas with moderate distances between them. This approach could enable sufficient numbers of new fish produced in the reserves to enter adjacent areas, to be harvested by fisheries.

- **Facilitate shared use agreements between potentially affected fishermen and wave park owners.** The Oregon Fishermen's Cable Committee, for instance, has been instrumental in developing and managing an agreement between the fishing industry and undersea fiber optic cable owners to minimize entanglements between fishing gear and cables, and resolve entanglements that occur. This agreement has served to enhance fishermen safety and reduce overall economic damages, and similar agreements (if needed) should be considered for wave energy parks. For instance, fisherman could receive annual lease payments as a form of profit sharing, provided that they do not interfere with wave energy equipment. Alternatively, wave energy companies could reimburse fisherman that snag and must (always) cut their gear from energy equipment.

- **Develop publicly owned and leasable wave cable networks during the R&D stage.** A large part of the initial installation expense is for the infrastructure to connect wave energy generators to the onshore power grid, and it would be advantageous to disperse this large capital cost among the small research-based firms that wish to test devices. This type of system (a "wave hub") is planned to be installed in Cornwall in 2010 to connect different types of prototype technologies for testing.

7. CONCLUSIONS AND RECOMMENDATIONS

The key findings of this report are listed below.

- **The construction periods of all three wave energy industry phases are expected to have the following impacts on the Oregon state economy:**
    - R&D Facility construction: $3 million in economic output and 48 jobs.
    - Wave Farm Commercial construction: $680 million in economic output and 4,089 jobs (assuming construction costs of about $750,000/MW).
    - Wave Cluster construction: $889 million in economic output and 6,032 jobs.
- **Operating the wave projects for one typical year is expected to have the following impacts on the Oregon state economy:**
    - R&D Facility operations: $13 million in economic output and 100 jobs.
    - Wave Farm Commercial operations: $57 million in economic output and 316 jobs.
    - Wave Cluster operations: $2.4 billion in economic output and 13,630 jobs.
- **The potential tax revenue impacts from wave energy are significant.** If the wave energy industry reaches the industrial wave cluster stage, it could produce over $56 million annually in new tax revenues for Oregon's coastal communities. On a statewide basis, the wave energy industry could produce over $90 million annually in new tax revenues.
- **The expected job impacts of the wave industry on the Oregon Coast are significant.** According to OLMIS, the total employment in Lincoln, Douglas, and Coos counties in 2007 was 80,629 jobs. The total job impacts of the three construction phases for the coastal economy are an estimated 3,547 new jobs, persisting for the length of construction process. Moreover, operating the wave projects is expected to generate and sustain more than 11,000 local jobs once the wave industry reaches the mature industrial stage.
- **The total economic impact of the commercial fishing industry for the Oregon economy in 2006 was $421 million in personal income.** Our study does not attempt to quantify the affect of the proposed wave energy projects on the fishing industry.

Based on these findings, it is clear that there is a significant economic potential for the wave energy industry if the technological and cost barriers can be addressed so the industry can progress to the commercial stage.

In addition to these considerations, we recommend that additional research be conducted in the following areas:

- **Increase understanding of environmental and economic relationship between wave energy and other coastal and ocean-based uses**. OWET is currently sponsoring several research studies to address these issues. We recommend that as soon as more information becomes available on potential environmental impacts, a more comprehensive economic impact study be conducted that quantifies any economic consequences (both positive and negative) due to wave energy environmental impacts, particularly as they relate to commercial and recreational fishing.

- **Update cost estimates for commercial wave facilities.** We have developed a general estimate of commercial wave study costs for this study, but more work in this area is needed. As wave energy prototypes are now being implemented, actual installation and energy production cost data should soon be available. We recommend that more research be conducted (using several different wave energy prototypes) to estimate the potential costs of creating commercially viable wave energy installations.