Economic Impact from Large-Scale Deployment of Offshore Marine and Hydrokinetic Technology in Oregon

T. Jimenez and S. Tegen

Produced under direction of the Bureau of Ocean Energy Management by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-12-1867 and Task No. WFQ4.1005.

This report is available from the Bureau of Ocean Energy Management by referencing OCS Study BOEM 2014-664. The report may be downloaded from the BOEM website through the Environmental Studies Program Information System (ESPIS) and may also be accessed on the BOEM Pacific Region website.

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

Technical Report
NREL/TP-5000-61727
January 2015

Contract No. DE-AC36-08GO28308

NATIONAL RENEWABLE ENERGY LABORATORY

Economic Impact from Large-Scale Deployment of Offshore Marine and Hydrokinetic Technology in Oregon

T. Jimenez and S. Tegen

Prepared under Interagency Agreement IAG-12-1867
and Task No. WFQ4.1005

This report is available from the Bureau of Ocean Energy Management by referencing OCS Study BOEM 2014-664. The report may be downloaded from the BOEM website through the Environmental Studies Program Information System (ESPIS) and may also be accessed on the BOEM Pacific Region website.

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

Technical Report
NREL/TP-5000-61727
January 2015

Contract No. DE-AC36-08GO28308

NOTICE

Study direction and funding were provided by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Pacific Region, Camarillo, CA, under Interagency Agreement IAG-12-1867 and Task No. WFQ4.1005. This report has been technically reviewed by BOEM and it has been approved for publication. The views and conclusions contained in this report are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

This manuscript has been authored by employees of the Alliance for Sustainable Energy, LLC (“Alliance”) under Contract No. DE-AC36-08GO28308 with the U.S. Department of Energy (“DOE”).

CITATION

Jimenez, T. and Tegen, S., 2014. Economic Impact of Large-Scale Deployment of Offshore Marine and Hydrokinetic Technology in Oregon. U.S. Department of Energy, National Renewable Energy Laboratory, Golden, CO, Technical Report NREL/TP-5000-61727. U.S. Department of the Interior, Bureau of Ocean Energy Management, Pacific Region, Camarillo, CA, OCS Study BOEM 2014-664. 35 pp.

Cover Photos: (left to right) photo by Pat Corkery, NREL 16416, photo from SunEdison, NREL 17423, photo by Pat Corkery, NREL 16560, photo by Dennis Schroeder, NREL 17613, photo by Dean Armstrong, NREL 17436, photo by Pat Corkery, NREL 17721.

NREL prints on paper that contains recycled content.

Acknowledgments

We would like to acknowledge the support of the Bureau of Ocean Energy Management (BOEM), which sponsored this work, and for the valuable advice and discussions provided by Thomas Liu and Jean Thurston of BOEM. We are grateful for the valuable discussions and suggestions from Matthew Sanders and Jason Busch of the Oregon Wave Energy Trust. Finally, we thank our colleagues at the National Renewable Energy Laboratory: Robert Thresher, David Keyser, Michael Lawson, Aaron Smith, Philipp Beiter, and Stuart Cohen for their generous sharing of time and knowledge, and to Fort Felker and Sheri Anstedt for careful review. This report would not have been possible without their support.

Executive Summary

The overall United States' marine and hydrokinetic (MHK) resource is comprised of river currents, ocean currents, and ocean wave energy. Of the three, wave energy has the greatest resource potential for electricity generation in the country. Within the continental United States, the West Coast in general, and Oregon in particular, appear to have the best wave energy resource. Wave energy resources are transformed into power by using wave energy converters, or WECs. MHK power is still in the stage of prototype devices and small demonstration projects[1]; however, this report explores scenarios with high deployment levels of WEC technology to investigate economic impacts for the State of Oregon, with the assumptions that technological advancements are made and costs are significantly decreased in the future.

To better understand the potential economic impacts of large-scale WEC technology, the Bureau of Ocean Energy Management commissioned the National Renewable Energy Laboratory to conduct this economic impact analysis of large-scale WEC deployment in Oregon.

The analysis examined two deployment scenarios in the 2026–2045 timeframe. The first scenario assumed 13,000 megawatts (MW) of WEC technology deployed in Oregon during the analysis period and the second scenario assumed 18,000 MW of WEC deployments. Sensitivity studies examined the effects of a robust in-state WEC-based supply chain and WEC device exports outside of Oregon.

The impacts highlighted here could be used in policy and planning discussions and could be scaled to get a sense of the economic development opportunities associated with other WEC deployment scenarios. In addition, the analysis can be used to inform stakeholders in other states about the potential economic impacts of this scale of WEC technology development. All estimates are based on currently available data, with caveats discussed in Section 2.1. It should be noted that scenarios in this report are hypothetical, and deployments of this magnitude would not realistically happen without advancements in technology and a very significant reduction in the cost of energy for WEC technology.

According to the analysis conducted in this study, deploying 13,000 MW of WEC installations in Oregon and assuming a medium-level in-state supply chain could[2]:

- Support a total of 6,800 operation-phase FTE jobs by 2045 when 13,000 MW have been deployed. Support 6,800 operation-phase jobs annually in the years following the analysis period for the remaining lifetime of the MHK projects
- Generate a total of $8.0 billion in economic activity for Oregon during the construction phases
- Support a total of $1.0 billion in economic activity by 2045 during operation phases. Generate $1.0 billion in annual economic activity in the years following the analysis period for the remaining lifetime of the MHK projects
- Provide $7.4 million in annual lease payments to the State of Oregon.

[1] According to the December 2013 Ocean Energy Systems Annual Report, the United Kingdom has 3,850 kilowatts of MHK capacity installed (Ocean Energy Systems 2013).

[2] Analysis results are provided in real 2012 inflation-adjusted U.S. dollars.

Figure ES-1 shows the estimated jobs in construction and operations for the years of the analysis.

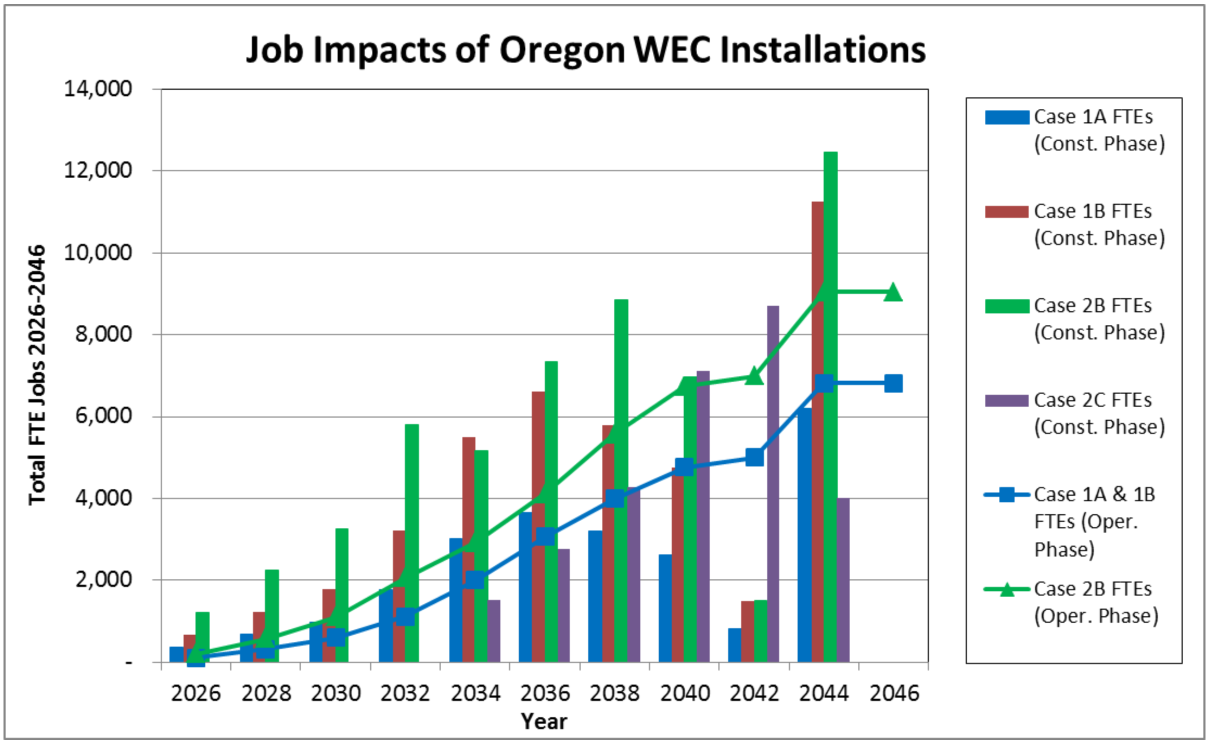

Figure ES-1. Estimated jobs in Oregon supported by WEC deployment scenarios

One key finding from this work is the sensitivity of the results to the magnitude of the in-state supply chain. Establishing an in-state supply chain that can manufacture even a modest portion of WEC installations would dramatically increase the economic impact of large-scale WEC deployment within the state.

Table of Contents

List of Figures

List of Tables

1 Introduction

Marine and hydrokinetic (MHK) technologies are in the early stages of development toward becoming a source of renewable energy, such as solar and wind power. MHK can be subdivided into two categories: current energy converters (CECs) and wave energy converters (WECs). CECs harness the power of river, tidal, and ocean currents and are similar to wind turbines, whereas WECs harness the energy of ocean surface waves (Thresher 2013). Figure 1-1 shows examples of some of the different WEC devices currently under development. The wide variety of topologies indicates that WEC technology is still immature. There are currently no commercial-scale, market-ready MHK devices deployed in the United States though there are some projects in the demonstration stages, with plans for larger devices. Figure 1-2 shows the U.S. wave energy resource.

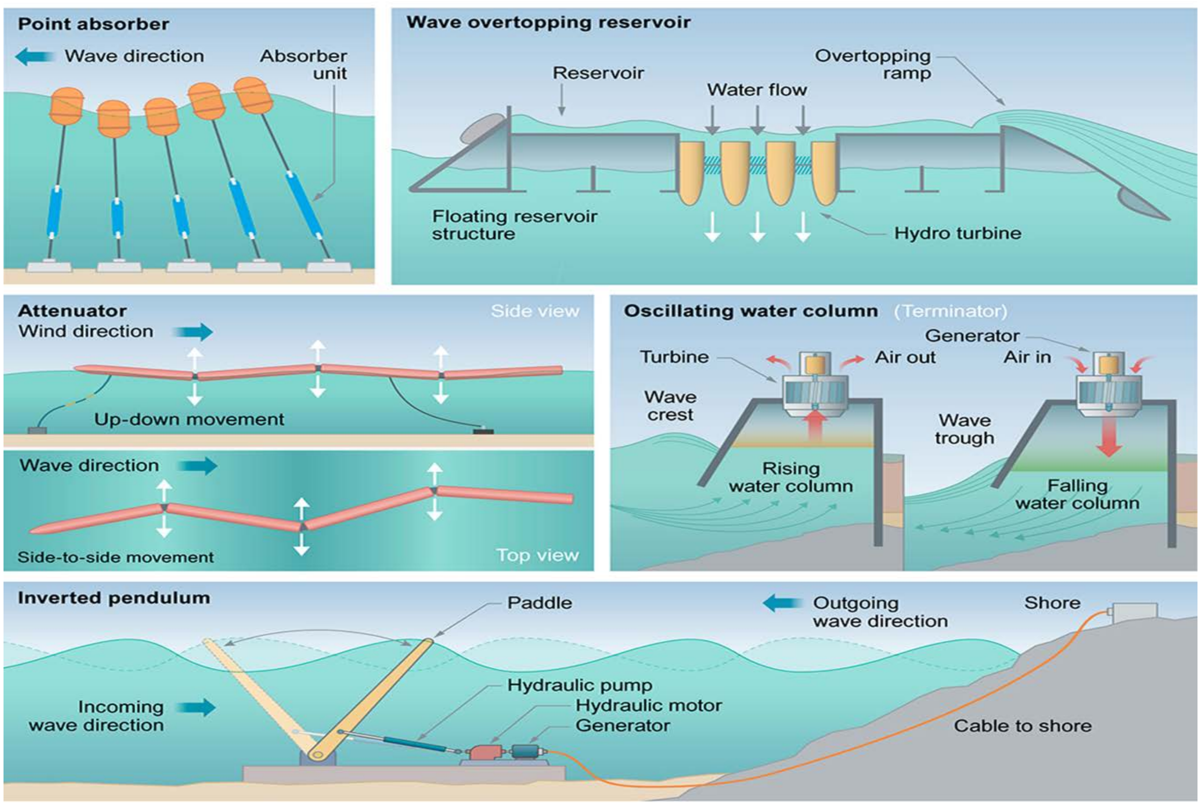

Figure 1-1. Wave energy conversion device topologies
Source: Augustine et al. 2012

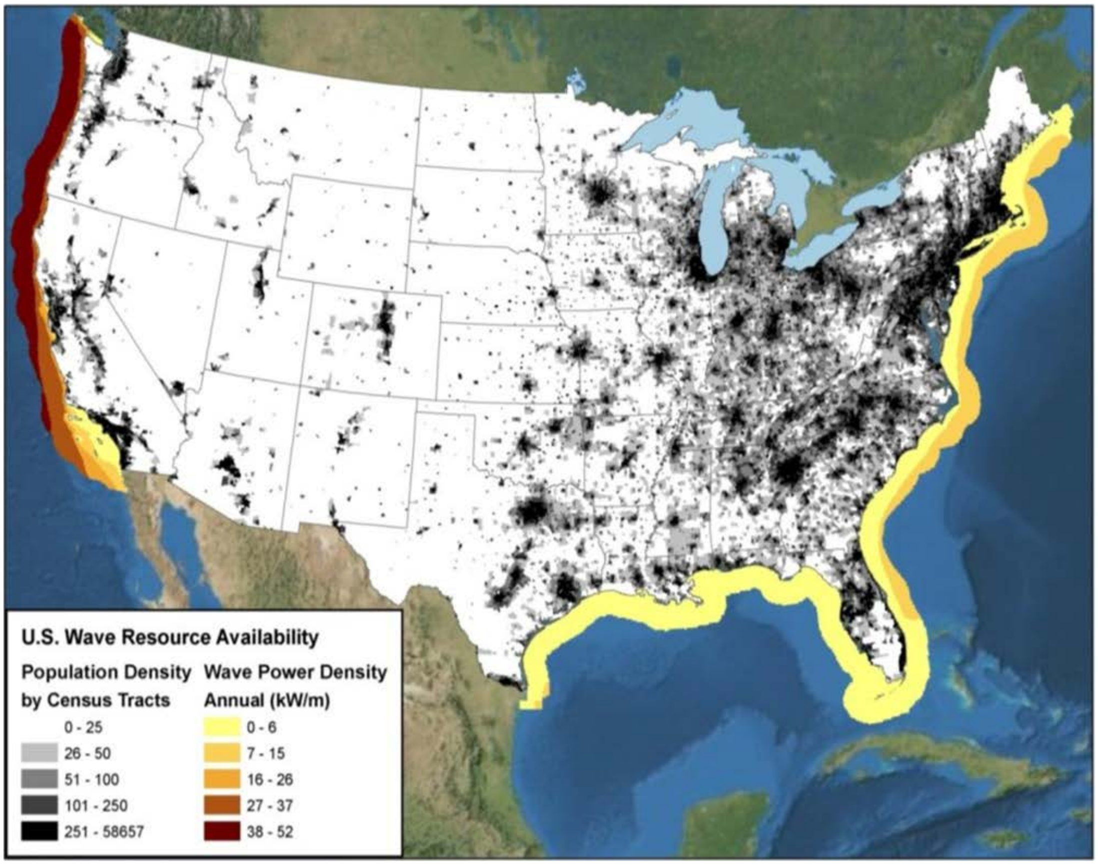

Figure 1-2. Annual estimated U.S. wave power density
Source: Thresher 2013; Resource data from *http://maps.nrel.gov/re_atlas*

At the request of the Bureau of Ocean Energy Management (BOEM), the National Renewable Energy Laboratory (NREL) conducted an analysis of the economic impacts of large-scale (10,000–20,000 megawatts [MW]) MHK, (specifically wave energy) deployment off the coast of Oregon. Oregon was selected because of its large wave energy resource and its ongoing efforts to create an Oregon-based wave energy industry. Specifically, NREL examined two different deployment scenarios using a large number of WEC deployments. Sensitivity studies were conducted to examine the effects of a larger in-state WEC supply chain and WEC device exports beyond Oregon.

Similar to utility-scale wind and solar, utility-scale MHK deployment is expected to support jobs and generate tax revenue that can be used to provide other public services. Estimating the potential economic development impacts of such power plants allows policymakers and decision makers to assess the impacts on jobs and state economic activity.

For the purposes of this study, state-level economic impacts include jobs, lease revenues, payrolls, and business activity from wave energy project development. Note that the described and quantified impacts are gross, not net impacts. In other words, the analysis does not account for potential job losses and reduced economic activity caused by the displacement of other types of electricity generating facilities and the displacement of other activities.

2 Methodology

2.1 The Jobs and Economic Development Impact Model

For this study, researchers used the MHK Jobs and Economic Development Impact (JEDI) model, which is one element of a suite of JEDI input-output (I-O) models. JEDI models provide gross estimated economic impacts that are supported by investment in a number of different energy technologies. NREL and MRG & Associates developed the MHK JEDI model to incorporate the unique aspects of MHK development into an economic impact tool that can be accessed and used by the public, at no cost.[3]

I-O models are widely recognized tools used to estimate economic impacts associated with investments or expenditures. These models map how sectors in an economy such as businesses, households, workers, capital, and government organizations interact with one another via purchases and sales at a single point in time. Because sectors are related to one another, an increase in demand for one can lead to an increase in demand for another. An increase in demand for a steel plate, for example, results in an increased demand for the iron ore that is sourced within the region of analysis.

JEDI and other I-O models estimate economic impacts that are supported by changes in demand for goods and services.[4] JEDI estimates changes in demand for these goods and services with data from the project scenario. The JEDI project scenario is a set of data that describes an energy generation project. Each project contains two sets of line item expense categories such as equipment, materials and services, and labor: one set covers the construction of the project and the other covers the operation and maintenance (O&M) of a project. JEDI models contain default project scenario and cost data, but analysts with knowledge of project details can edit these defaults to better represent the scenario being analyzed.

The JEDI model requires users to specify the portions of expenditures that are made within the region of analysis, i.e., the "local share." For example, the model allows users to specify the fraction of the "device" purchased from in-state manufacturers (assuming that the state is the region of analysis). JEDI uses expenditures made within the region of analysis, or "local expenditures," to estimate economic impacts (for example, WEC devices manufactured within the State of Oregon). The JEDI model does not estimate economic impacts outside the particular region of analysis (e.g., generator parts from China).

JEDI reports economic impact estimates for two phases: construction and O&M. Construction-phase results are one-time totals that span the equivalent of 1 year,[5] and O&M phase results are annual and ongoing for the life of the facility.

---

[3] The MHK JEDI model can be downloaded at http://www.nrel.gov/analysis/jedi/download.html. Accessed February 12, 2014.

[4] JEDI currently uses the IMPLAN input-output model. More information about IMPLAN can be found at http://www.implan.com.

[5] If, for example, JEDI reports a construction-phase impact of 50 workers to build a project that takes 2 years to complete, this equates to an average of 25 workers per year (50/2 = 25). If the same project took 3 years, the average would be 17 (rounded) workers per year.

All impacts are based on expenditures and local content data contained within the project scenario worksheet. JEDI organizes these effects into different categories based on how the user-specified project scenario supports the impact. The workers who install a wave energy project, for example, are on site. The workers who manufacture the wave energy device are part of the supply chain. Installers and manufacturers earn wages and spend money within the region of analysis, which supports further economic activity (e.g., the construction workers eat lunch at local sandwich shops). The three categories of impacts used by JEDI are[6]:

- **Project development and on-site labor impacts.** This category represents the economic activity that is either directly involved with a project's development and implementation or that occurs on site. These impacts typically occur in the construction, maintenance, engineering, and port-staging sectors and do not include impacts that arise from expenditures for inputs used in a project.
- **Plant and supply chain impacts.** This category represents the economic activity that is supported by inputs purchased for a project or business-to-business services. These include locally manufactured inputs, such as the WEC conversion equipment (also referred to as the "device"), and locally procured inputs used to manufacture the device, such as steel and fiberglass. This category also includes services provided by professionals such as analysts and attorneys who assess project feasibility and negotiate contract agreements, banks that finance the projects, and all equipment companies and manufacturers of replacement and repair parts.
- **Induced impacts.** This category represents the impacts of money circulating in an economy. Households spend earnings generated from employment in project development and development activities as well as turbine and supply chain activities. A portion of these earnings spent within the region of analysis supports induced impacts, examples of which include retail sales, child care, leisure, hospitality, and real estate services. (Goldberg and Previsic 2011)

Figure 2-1 shows the three categories of impact from the JEDI model.

[6] Typically, I-O models organize impacts into direct, indirect, and induced effects, but JEDI categories are different. Project development and on-site labor impacts include less than direct effects from project expenditures and turbine, and supply chain impacts are more broad than the indirect effects from project expenditures. The MHK Wind JEDI User Reference Guide (http://www.nrel.gov/analysis/jedi) provides more information about these differences.

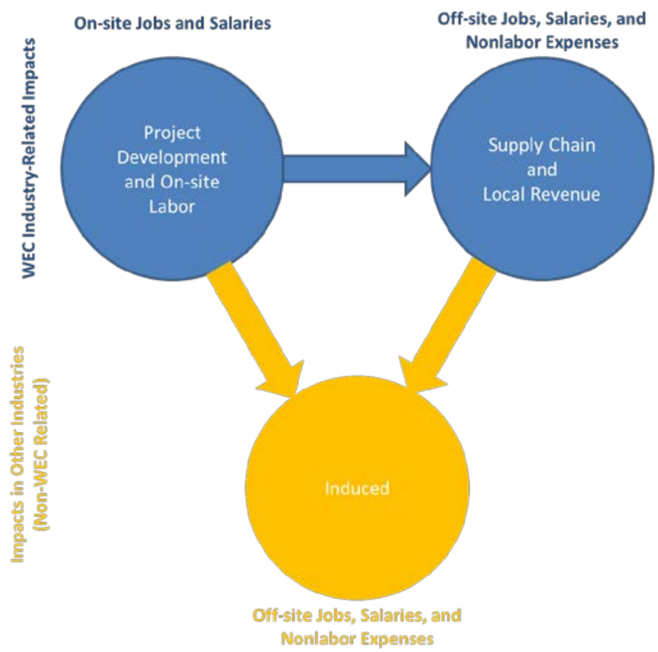

Figure 2-1. JEDI Wind model economic development impact categories

JEDI reports three different metrics for each type of impact: jobs, earnings, and gross output, and utilizes intuitive labels when reporting these metrics, such as "jobs" and "earnings." Each metric, however, has a specific definition that informs how it should be interpreted, as follows.

- **Jobs** are expressed as full-time equivalent (FTE) jobs. One FTE job is the equivalent of one person working 40 hours per week, year-round. Two people working full-time for 6 months equal one FTE. Two people each working 20 hours/week for 12 months also equal one FTE. An FTE could alternately be referred to as a person-year or job-year. Jobs, as reported by JEDI, are not limited to those who work for an employer—and may include other types of workers, such as sole proprietors (individuals that are self-employed).
- **Earnings** include any type of income generated from work, generally an employee's wage or salary and supplemental costs paid by employers such as health insurance and retirement. They may also include other nonwage compensation for work performed such as proprietor earnings.
- **Total economic activity (output)** is the sum of all expenditures. For example, a scenario in which a developer purchases a locally manufactured $500,000 WEC component that utilized $100,000 of locally procured aluminum represents $600,000 in gross output.

As with all economic models, there are caveats and limitations to the use of JEDI. I-O models in general utilize fixed, proportional relationships between sectors in an economy. This means that factors that could change these relationships, such as price changes that lead households to alter consumption patterns, are not considered.

JEDI provides estimates of gross economic impacts based on the user-specified expenditures and economic conditions provided when the input-output data were compiled. Impacts that extend into the future (such as O&M impacts) are assumed to do so if all else is constant. There can be any number of changes in a dynamic economy that JEDI does not consider, so these future results should not be considered as a forecast. They simply reflect how a project might look if it was completed in the current economy under the user-specified cost and local content assumptions.

JEDI results are based on project inputs, and these inputs can change from project to project. These changes in input values are especially true of nascent technologies, or technologies that have not yet been widely deployed in the United States. If an analyst wishes to estimate impacts from a specific project, tailoring inputs to that project should produce more accurate results. JEDI does not evaluate whether or not inputs are reasonable, nor does it determine whether a project is feasible or profitable.

As stated, results from JEDI models are gross, not net. JEDI estimates economic activity that would be supported by demand created by project expenditures. Other changes in an economy will take place that JEDI does not consider, such as price changes, changes in taxes or subsidies, utility rate changes, or changes in property values. JEDI also does not incorporate far-reaching effects such as greenhouse gas emissions or displaced investment, or potential effects of a project such as changes in fishing, recreation, or tourism.

2.2 Research Data and Assumptions and Methodology

This analysis consists of two main parts. The first part consists of the development or selection of MHK deployment scenarios. The second part explains our analysis of the economic impacts of those deployment scenarios.

2.2.1 Deployment Scenarios Description

We present four cases that examine two deployment scenarios. Sensitivity studies examine the effects of a larger in-state supply chain and WEC device exports to locations beyond Oregon. Table 2-1 summarizes the four cases analyzed for this effort. Cases 1A and 1B both assume the deployment scenario in which West Coast-based WEC installations supply 80 TWh of electricity annually by 2050.[7] Case 1A assumes that on average 20% of the WEC devices are sourced by in-state OEMs, i.e., a 20% local share, whereas Case 1B assumes a 60% local share for the WEC device. Case 2B assumes an even higher deployment scenario in which West Coast WEC installations supply 160 TWh of electricity annually by 2050, with a 60% WEC device local share. Case 2B is quite aggressive, representing an estimated 3% of the entire U.S. electricity demand by 2040 (likely a smaller percentage in 2050; however, the Energy Information Administration projections end in 2040 [EIA 2014b]). Each of these three cases examines the economic impact to Oregon from WEC facilities.

In contrast, Case 2C assumes that Oregon device manufacturers export out of state. Case 2C assumes that Oregon-based OEMs supply 25% of the devices for installations in Washington and California under the higher (160 TWh) deployment scenario. For this analysis, the destination of the exports does not matter. Destinations could also include Alaska, Hawaii, the East Coast, and

[7] Though it is impossible to make accurate projections so far into the future, based on Energy Information Administration projections (see EIA 2014b), 80 TWh would be between 1%–2% of the United States' electricity consumption in the 2040–2050 timeframe.

foreign countries. The results for this case are the economic impacts to Oregon, from these exports. For this case, the device local share (from Oregon) is set to 25%. For all other items, the value of the local share is set to zero. Note that the impacts of exports are in addition to the impacts of in-state installations. In other words, the impacts of Case 2C are in addition to the impacts of the already optimistic Case 2B.

According to the Energy Information Administration, "[r]enewable resources contribute over two-thirds of the net electricity generation in Oregon. In years with increased or prolonged precipitation or snowmelt, renewable resources contribute as much as four-fifths of net electricity generation, because of the state's abundant hydroelectric generation capacity […]. From 2007 through the end of 2013, [Oregon] electricity generation from non-hydroelectric renewable resources almost quadrupled." (EIA 2014a).

Table 2-1. Analysis Cases

Case Label	Deployment Scenario	Sensitivities
1A	80 TWh scenario	20% device local share
1B	80 TWh scenario	60% device local share
2B	160 TWh scenario	60% device local share
2C	160 TWh scenario	25% device local share (from Oregon suppliers) for installations in California and Washington

The deployment scenarios used in this analysis come from hypothetical deployment scenarios for wave energy technology that explore the potential impacts of R&D improvement pathways and manufacturing learning effects on the cost of energy over long time periods (Cohen 2013; Thresher, 2013; Thresher, 2014). The hypothetical scenarios forced the deployment of WEC technology according to a specified deployment schedule without regard for its cost and then estimated the overall capital cost under differing improvement and learning assumptions using the Regional Energy Deployment System (ReEDS) Model. ReEDS is a long-term capacity-expansion model for the deployment of electric power generation technologies and transmission infrastructure throughout the contiguous United States.[8] For a given set of economic, policy, and load growth assumptions, ReEDS models the deployment of transmission infrastructure as well as various conventional and renewable energy generation technologies. Within the constraints of the scenario, ReEDS will meet the anticipated load by using the least expensive (on a lifecycle cost basis) combination of transmission and generation. As stated, for the purpose of this analysis, we forced the ReEDS model to deploy WEC regardless of costs.

The ReEDS analysis examined two deployment scenarios: one in which WEC installations supply approximately 80 terawatt-hours (TWh) of electricity per year to the West Coast by 2050, and the other in which WEC technology supplies twice that amount, 160 TWh, by 2050. It is important to note that that these scenarios are hypothetical, and deployments of this magnitude

[8] http://www.nrel.gov/analysis/reeds/description.html

would not realistically happen without advancements in technology and a very significant reduction in the cost of energy for WEC technology. ReEDS estimates energy generation deployment by state, thus providing Oregon-specific WEC deployment values. Both deployment scenarios supply significant portions of the energy needs for the West Coast. We selected 2026 to 2045 as our analysis period because it captures the bulk of Oregon-based wave energy installations occurring within the ReEDS scenarios.

The scenarios for the ReEDS investigation also include cost estimates, both capital and O&M, for the wave energy facilities. Compared to wind or solar energy, wave energy technology is still immature and costly. Current estimated installed capital expenditures (CAPEX) for wave energy plants are more than $8,272/kW. Current operating expenditures (OPEX) are estimated at $400/kilowatt (kW)/year. These values are a composite from several studies (Prevesic 2012; Renewable UK 2010; Department of Trade and Industry 2007). Although these costs are high, cost reduction opportunities exist. The future scenarios analyzed here would require significant cost reductions over time resulting from technology improvements, acquiring knowledge, and a robust research and development program.

Table 2-2 shows the hypothetical annual wave energy deployment in Oregon, as well as the CAPEX and OPEX, for both scenarios. Also shown are combined installations for California and Washington under the 160 TWh scenario. The 80 TWh scenario shows roughly 13,000 MW of wave energy deployment off the coast of Oregon by 2045, while the 160 TWh scenario predicts over 18,000 MW. Note that the higher scenario does not represent twice the deployment, in Oregon, of the lower scenario. Because of Oregon's excellent wave energy resource, the state could reach significant levels of deployment, were technology advancements and cost reduction to occur. As overall west coast deployment increases in the scenario, Oregon is saturated, and more development starts to occur in lower wave energy resource areas.

Both deployment scenarios envision sharp drops in both CAPEX and OPEX from the present baseline values of $8,272/kW and $400/kW/year. In the 80 TWh scenario, CAPEX and OPEX drop to $1,098/kW and $53/kW/year by the end of the analysis period. For the 160 TWh scenario, the respective costs at the end of the analysis period are $966/kW and $47/kW/year – a very significant prescribed decrease. The cost reductions assumed here are ambitious and would take substantial technological improvements, but were modeled to show impacts from a future in which WECs have had large cost reductions. It can be noted that both wind and photovoltaic technologies have undergone similar levels of cost reduction, so the scenarios are only possible if WEC technology proves to be robust and reliable. Again, it must be emphasized that only with the development of sound technology options and cost reductions (as shown here) could the large-scale deployment of WEC technology be possible.

Table 2-2. Oregon Wave Energy Deployment Scenarios *(Costs given in 2012 dollars)*

80 TWh Scenario			
Year	Installed (MW)	Installed Cost ($/kW)	Investment ($MM)
2016	5	$8,272	$41.36
2018	6	$8,272	$50
2020	12	$4,963	$60
2022	24	$4,960	$119
2024	48	$3,122	$150
2026	99	$2,809	$278
2028	199	$2,528	$503
2030	397	$1,824	$724
2032	775	$1,669	$1,293
2034	1,475	$1,502	$2,215
2036	1,945	$1,370	$2,665
2038	1,836	$1,269	$2,330
2040	1,613	$1,182	$1,907
2042	530	$1,140	$604
2044	4,117	$1,098	$4,520
Cumulative	13,081		

160 TWh Scenario			
Year	Installed (MW)	Installed Cost ($/kW)	Investment ($MM)
2016	11	$8,272	$90.99
2018	11	$8,272	$91
2020	23	$4,963	$114
2022	47	$4,464	$210
2024	97	$2,810	$273
2026	197	$2,528	$498
2028	398	$2,277	$906
2030	790	$1,663	$1,314
2032	1,570	$1,490	$2,339
2034	1,540	$1,349	$2,077
2036	2,405	$1,228	$2,953
2038	3,117	$1,141	$3,556
2040	2,647	$1,059	$2,803
2042	593	$1,015	$602
2044	5,024	$996	$5,004
Cumulative	18,470		

160 TWh Scenario (WA+CA)			
Year	Installed (MW)	Installed Cost ($/kW)	Investment ($MM)
2016	0	$0	$0.00
2018	0	$0	$0
2020	0	$0	$0
2022	0	$0	$0
2024	0	$0	$0
2026	0	$0	$0
2028	0	$0	$0
2030	0	$0	$0
2032	0	$0	$0
2034	1,582	$1,363	$2,157
2036	3,220	$1,235	$3,978
2038	5,373	$1,141	$6,132
2040	9,579	$1,065	$10,203
2042	12,152	$1,027	$12,482
2044	5,810	$986	$5,731
Cumulative	37,716		

2.2.2 Methodology

Our research on costs and cost breakdowns consisted of a literature review (ECONorthwest 2009; Carbon Trust 2011; Previsic et al. 2012). We conducted interviews with internal experts and MHK stakeholders to provide depth and validation to the analysis. Data obtained from interviews included construction costs, O&M costs, percentage of goods and services acquired in-state, job generation during the construction period, job generation during the operation period, land-lease payments, tax information, payroll parameters, and the cost breakdown of different installation and operation categories.

Using the information derived from the sources noted above, we developed specific assumptions including construction cost breakdown (Table 2-3), operating cost breakdown (Table 2-4), local (in-state) share for both CAPEX and OPEX, and other relevant parameters (Table 2-5), which were used as inputs in the JEDI model.

Table 2-3. Construction Cost Assumptions

Construction	% of Total Cost	Local Share
Equipment & Material		
Device	69.2%	20%/60%/25%
Underwater Electrical Collector System	7.8%	10%
Underwater Transmission Cable	1.3%	10%
Cable Landing and Grid Interconnection	1.9%	10%
Balance of Plant	4.1%	80%
Equipment & Material Subtotal	*84.3%*	
Installation/Labor		
Mooring and Device Installation	6.8%	80%
Underwater Cable Installation	5.5%	10%
Cable Landing and Grid Connection	1.4%	80%
Installation/Labor Subtotal	*13.7%*	
Permitting		
Permitting	2.0%	75%
Permitting Subtotal	*2.0%*	
Sales Tax (Material and Equipment Purchases)		
Sales Tax (Materials and Equipment Purchases)	0.0%	100%
Sales Tax Subtotal	*0.0%*	
Total	**100.0%**	

Tables 2-3, 2-4, and 2-5 show the assumptions behind the analysis. Local share refers to the percentage of resources (e.g., labor, materials, supplies, and equipment) purchased or acquired in Oregon. Three values of the local share are given for the "device." The lower 20% value assumes no continued special effort to develop an Oregon-based WEC industry. The higher 60% value assumes a successful, aggressive effort to develop a large Oregon-based WEC industry and that the majority of the nonelectrical equipment is sourced by Oregon-based OEMs. The 25% value for local share is used in Case 2C and assumes that Oregon-based manufacturers achieve an export volume equivalent to 25% of the combined WEC installations in Washington and California.

A large underwater electrical component industry already exists outside of Oregon, so the local share for these items is anticipated to be very low. In addition, underwater cable installation uses specialized vessels that are not based in Oregon, thus the low value for the local share of the labor for the underwater cable installation. Equipment costs represent about 84% of the total project cost, labor represents 14%, and permitting represents 2%.

Figure 2-2 shows the average cost breakdown assumptions used as inputs for this study.

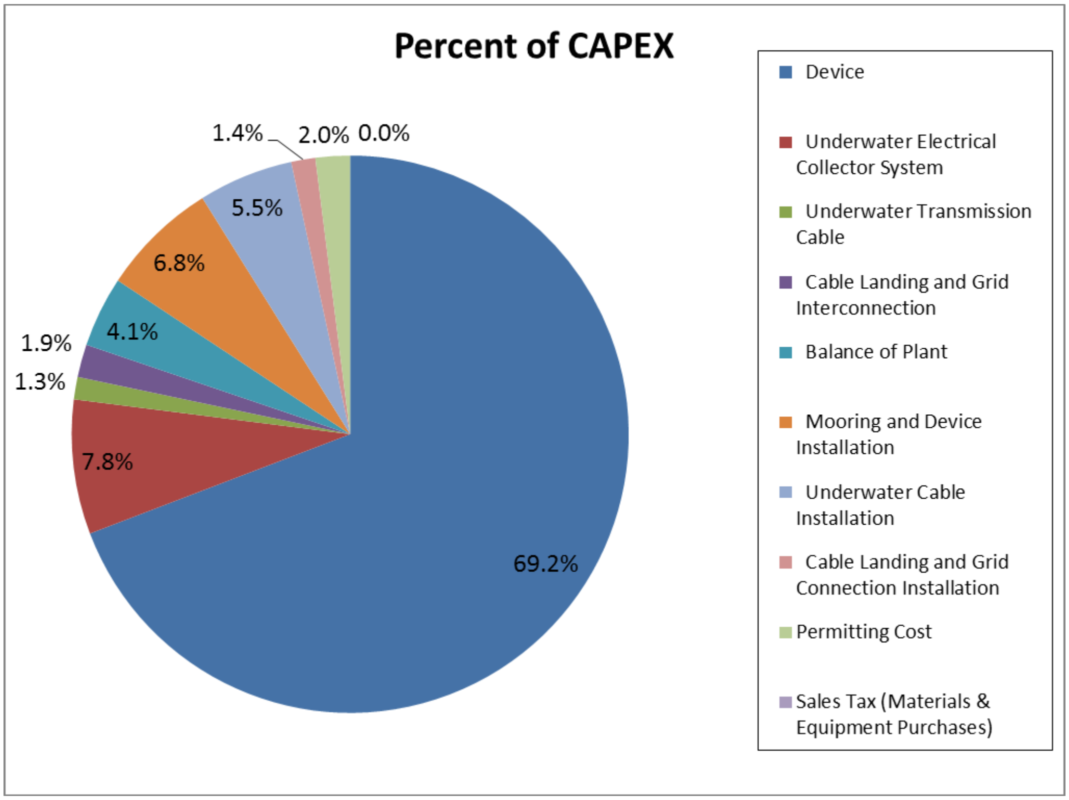

Figure 2-2. Construction cost breakdown assumptions

Table 2-4 shows the operating expenditure breakdown. Operating costs are assumed to be 4.8% of the capital cost and are comprised of just over 20% labor and fewer than 80% for materials and services. For both of these items, the local share is anticipated to be relatively high. We anticipate that most O&M workers will either already live in-state or settle within the state to perform their jobs.

Table 2-4. Operating Cost Assumptions

Wind Farm Annual Operating and Maintenance Costs	% of Total Cost	Local Share
Labor		
Labor	21.1%	80%
Labor Subtotal	*21.1%*	
Materials and Services		
Material and Services	78.9%	70%
Materials and Services Subtotal	78.9%	
Sales Tax (Materials and Equipment Purchases		
Sales Tax	0.0%	100%
Sales Tax Subtotal	*0.0%*	
Total O&M Cost	**100.0%**	

Table 2-5 shows the additional parameters considered in the analysis. Because of the large capital investment required, the analysis assumes that 100% of the investment for the WEC facilities comes from out of state (i.e., the local share is zero.) Deployment on the scale assumed for this analysis will require a total investment of $10–$20 billion.

As a result of assuming a zero local share for the investment, the only value in this section affecting the results is the lease rate. For lease purposes, the offshore facilities will fall into one of three zones. Facilities located within 3 miles of the shoreline are located in state waters and will be subject to lease rates determined by the State of Oregon. Facilities located in federal waters, greater than 3 miles from shore, must receive a lease from BOEM. For projects located 3–6 miles offshore, the state is entitled to 27% of the lease revenue. For projects located beyond 6 miles from shore, the state receives no lease revenue. Facilities located in federal waters may also be subject to Federal Energy Regulatory Commission fees. However, the state share of these fees is zero, (Bowler 2014) thus these fees have no economic impact to Oregon.

It is anticipated that most installations will be conducted in water with depths of 50 meters (m)–100 m. For Oregon, this depth of water is generally located 3–6 miles offshore. Therefore, it is reasonable to assume that the majority of the installations will be positioned within this zone. To the extent facilities are located more than 6 miles offshore; Oregon will receive less lease revenue. To the extent facilities are located within state waters, Oregon will receive more lease revenue.

The BOEM lease rate used in the analysis is based on a precedent from four offshore leases for planned wind plants to be located in federal waters (BOEM 2010, 2013a, 2013b, 2013c). For these projects, the initial operational period lease rate is 2% of product of the facility's energy production and the average regional wholesale electricity rate. The lease rate used in the analysis assumes a 30% capacity factor, an average wholesale price of $0.04/kilowatt-hour. Of the total BOEM lease revenue, 27% goes to the State of Oregon. (O'Neil 2014)

Table 2-5. Additional Study Parameters Considered

Additional Parameters	Value	Local Share
Financial Parameters		
Percentage Financed	50%	0.0%
$ Years Financed (term)	20	
Interest Rate	7%	
Percentage Equity	50%	
Corporate Investors (percent of total equity)	90%	0.0%
Individual Investors (percent of total equity)	10%	0.0%
Return on Equity (annual interest rate)	12%	
Tax Parameters		
Local Property Tax (percent of taxable value)		
Assessed Value (percent of construction cost)		
Taxable Value (percent of assessed value)		
Property Tax Exemption (percent of local taxes)		
Local Property Taxes		0%
Local Sales Tax Rate		
Lease Cost (if applicable)		
Lease Cost ($/MW/year)	$2,102	27%

3 Results

NREL researchers used the JEDI model to estimate the economic impact of each of the four cases, and results indicate that the impacts would be significant, given the prescribed robust deployment scenarios. Figure 3-1 summarizes the impacts for Case 1A. This case assumes the 80 TWh deployment scenario and lower local share for the WEC device.

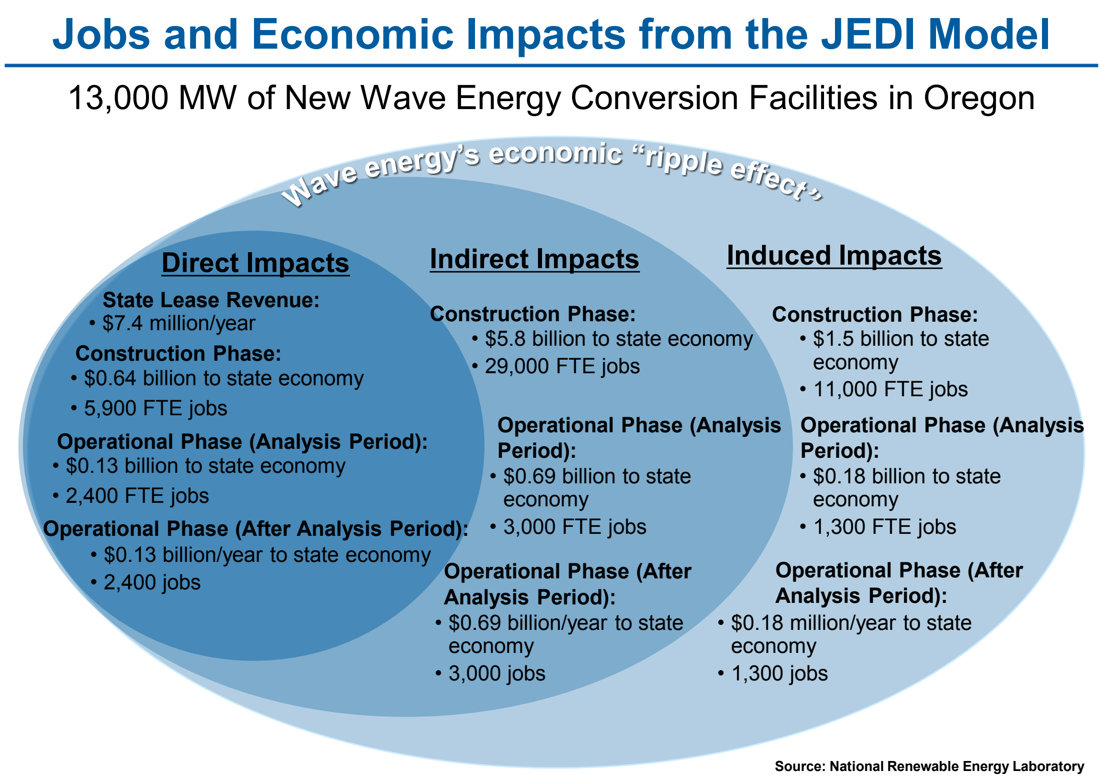

Figure 3-1. Economic ripple effect from 13,000 MW of WEC facility deployments in Oregon from 2026 to 2045 (assuming 20% in-state device share)

Table 3-1 summarizes the impacts for all four cases. Impacts reported are centered on JEDI model results, which include employment, property taxes, and local economic activity during the construction and operation periods. Although estimating all WEC-related impacts was beyond the scope of this analysis, new WEC installations may have many other tangible (e.g., use tax generation, sales tax generation, water savings, vendor profits, and transmission line impacts) and intangible impacts (e.g., electricity price stability and environmental benefits). For the operations period, Table 3-1 shows the number of O&M-related jobs in the year 2045, when the scenario has reached full deployment capacity. This level of employment is expected to continue for O&M-related jobs through the end of the lifetime of the project.

Table 3-1. Oregon Summary Impacts[9] from WEC Deployment (2026–2045)

	Case 1A	Case 1B	Case 2B	Case 2C
Jobs (FTE)	**TOTAL**	**TOTAL**	**TOTAL**	**TOTAL**
During construction and installation period				
Project Development and Onsite Labor Impacts	5,899	5,899	7,648	0
Construction and Installation Labor	3,290	3,290	4,258	0
Construction and Installation Related Services	2,609	2,609	3,390	0
Equipment and Supply Chain Impacts	29,312	57,322	74,257	41,796
Induced Impacts	11,385	21,461	27,778	15,035
Total Impacts	**46,597**	**84,682**	**109,683**	**56,830**
During operating years (by 2045)				
Onsite Labor Impacts				
WEC Project Labor Only	2,436	2,436	2,765	0
Local Revenue and Supply Chain Impacts	3,058	3,058	4,420	0
Induced Impacts	1,326	1,326	1,854	0
Total Impacts	**6,820**	**6,820**	**9,039**	**0**
Earnings ($MM)	**TOTAL**	**TOTAL**	**TOTAL**	**TOTAL**
During construction and installation period				
Project Development and Onsite Labor Impacts	$ 343	$ 343	$ 435	$ -
Construction and Installation Labor	$ 153	$ 153	$ 188	$ -
Construction and Installation Related Services	$ 190	$ 190	$ 247	$ -
Equipment and Supply Chain Impacts	$ 1,732	$ 3,482	$ 4,509	$ 2,611
Induced Impacts	$ 485	$ 913	$ 1,182	$ 640
Total Impacts	**$ 2,560**	**$ 4,738**	**$ 6,127**	**$ 3,251**
During operating years (by 2045)				
Onsite Labor Impacts				
WEC Project Labor Only	$ 129	$ 129	$ 146	$ -
Local Revenue and Supply Chain Impacts	$ 179	$ 179	$ 260	$ -
Induced Impacts	$ 56	$ 56	$ 79	$ -
Total Impacts	**$ 364**	**$ 364**	**$ 485**	**$ -**
Output ($MM)	**TOTAL**	**TOTAL**	**TOTAL**	**TOTAL**
During construction and installation period				
Project Development and Onsite Labor Impacts	$ 637	$ 637	$ 817	$ -
Equipment and Supply Chain Impacts	$ 5,849	$ 12,639	$ 16,365	$ 10,132
Induced Impacts	$ 1,527	$ 2,878	$ 3,725	$ 2,016
Total Impacts	**$ 8,013**	**$ 16,154**	**$ 20,907**	**$ 12,148**
During operating years (by 2045)				
Onsite Labor Impacts				
WEC Project Labor Only	$ 129	$ 129	$ 146	$ -
Local Revenue and Supply Chain Impacts	$ 692	$ 692	$ 1,008	$ -
Induced Impacts	$ 178	$ 178	$ 249	$ -
Total Impacts	**$ 999**	**$ 999**	**$ 1,403**	**$ -**

[9] Results are provided in real 2012 U.S. dollars.

3.1 Gross Economic Activity

As shown in Table 3-1, the modeled scenario's construction and operation of WEC facilities is combined with significant economic activity in Oregon. From rented accommodations that host the influx of construction workers to the suppliers and transportation companies that provide equipment, supplies, and services to the WEC facilities, this modeled WEC development results in a substantial impact to the state economy.

Depending on the device local share, 13,000 MW of WEC facilities in Oregon (Cases 1A and 1B) could generate approximately $8–$16 billion in gross economic activity during the construction phase and a total of $1 billion in economic activity by 2045 during the operations phase. The lower $8 billion construction phase value assumes a device local share of 20%, which means that Oregon-based OEMs provide 20% of the WEC device capacity for Oregon installations. The higher value, $16 billion, assumes that Oregon-based device suppliers provide 60% of Oregon installations. Raising the device local share from 20% to 60% increases the total equipment and supply chain construction phase impacts from $5.8 to $12.6 billion. In turn, the increased supply chain economic activity increases the induced construction phase impacts from $1.5 to $2.9 billion.

The large variation in construction phase economic activity shows the importance of the in-state or "local" content of the parts and equipment used in MHK power generation. Recall from Table 2-3 or Figure 2-2 that the "device," (the WEC energy conversion equipment) represents almost 70% of the capital cost of a WEC installation. Thus, the total economic impact of a WEC installation depends heavily on the proportion of the "device" that is supplied from within the analysis area (the State of Oregon in this case). The device local share would have a similarly large impact on overall construction-phase jobs and earnings impacts.

Assuming the larger deployment scenario of more than 18,000 MW of WEC facilities, along with a 60% device local share (Case 2B), results in almost $23 billion of construction-phase gross economic activity and $1.4 billion total operations phase economic activity by 2045. Finally, assuming that Oregon-based suppliers export a volume of devices equal to 25% of combined Washington and California installations (Case 2C), results in an additional $12 billion in construction-phase economic activity over the study period.

The impacts noted above include only the portion of transactions that take place in Oregon. For example, equipment and components that were purchased from other states or other countries are treated as monetary leakages and are not included in these estimates. Case 1A assumes that 13,000 MW of WEC installations represent $17 billion[10] in investment, which supports over $8 billion in state-level economic activity. This $8 billion in economic activity is comprised of approximately $0.6 billion in on-site project labor, $5.8 billion in construction materials and supply chain equipment, and $1.5 billion in induced activities during the construction period (Figure 3-2).

[10] 2012 U.S. dollars

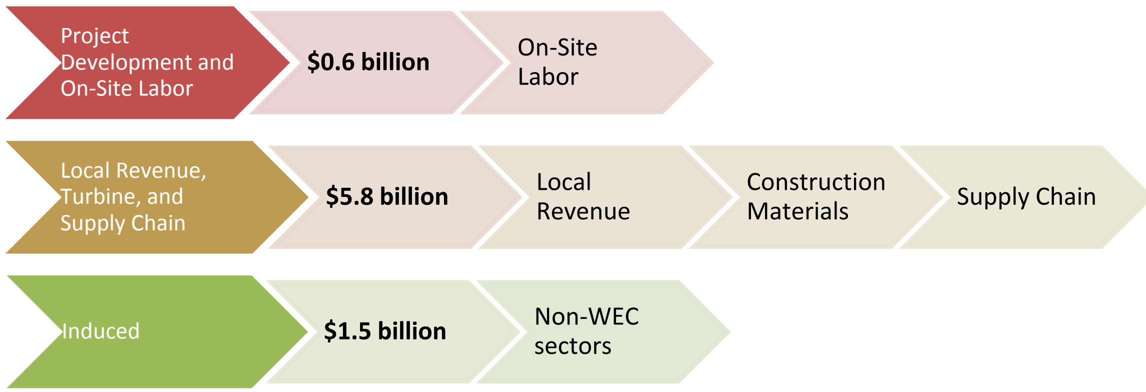

Figure 3-2. Estimated local spending supported by 13,000 MW of WEC facilities in Oregon during project construction (assuming 20% device local share)

Figure 3-3 shows the impacts of each case throughout the analysis period. The figure goes two years beyond the end of the analysis period to show the operational period impacts of the WEC facilities installed during the final 2-year installation cycle (2044–2045). As shown in Figure 3-3, construction-phase impacts vary over time depending on the amount of WEC capacity installed in each period. Operation phase impacts grow over time as the cumulative WEC capacity increases.

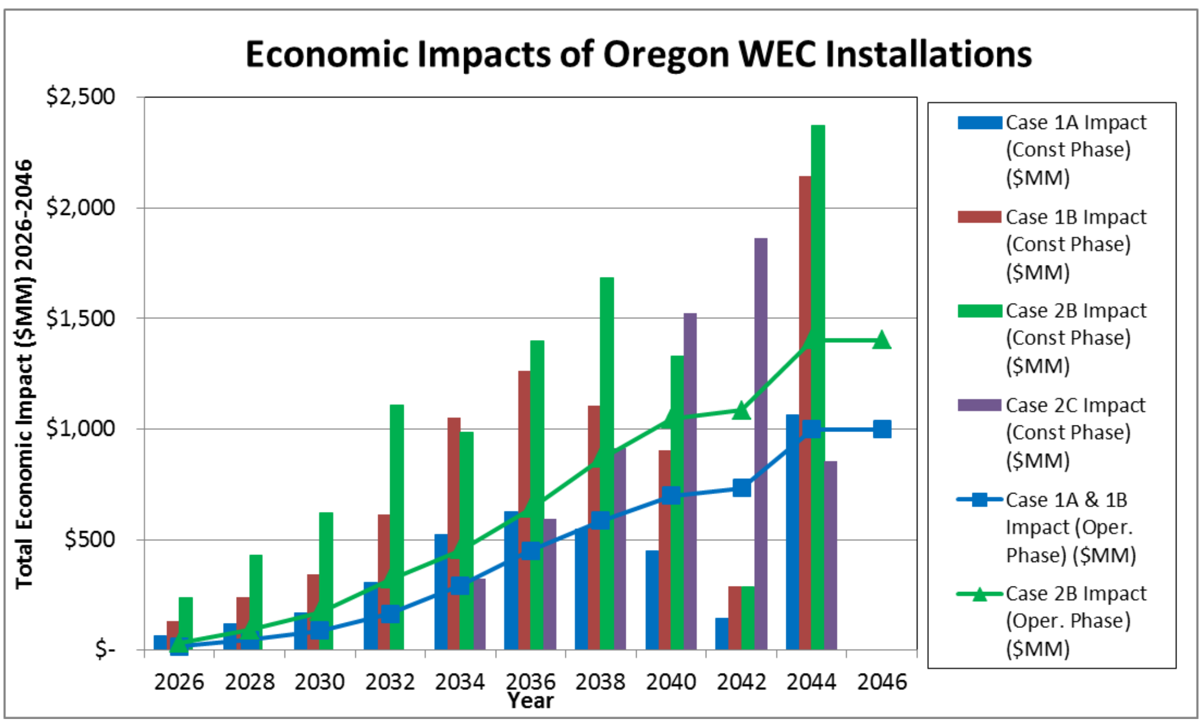

Figure 3-3. Estimated total economic impacts from WEC deployment in Oregon throughout the analysis period

3.2 Employment Impacts

3.2.1 Construction Jobs

During the construction phase, construction workers, engineers, surveyors, WEC installers, electrical contractors, administrative employees, and managers who live in the project location boost local economic activity. Local workers may be employed directly at the new WEC facility, depending on the talent pool and skill set in the area. Other workers from outside the state may settle within the state. Another category of workers reside out of state and only live within the state during the construction phase, moving on when construction is complete. Workers who reside in-state spend their earnings on mortgage payments, insurance, childcare, education, utilities, tax payments, family entertainment and recreation, clothing, and so on. Workers from out of state generate a different set of economic impacts. These temporary workers support a smaller ripple effect in the state economy because most of their earnings are spent outside of the state, with a smaller portion circulating through the Oregon economy. Most of their impacts are limited to spending on lodging, food, beverages, and transportation, which is often subsidized by the construction company. Out-of-state workers' earnings were not included in this analysis.[11]

The number of employees building a WEC facility depends on the construction stage of the project. For example, the peak construction stage may require a significantly higher number of workers than the initial and final stages. Figure 3-4 shows the year-by-year job impacts for the four cases.

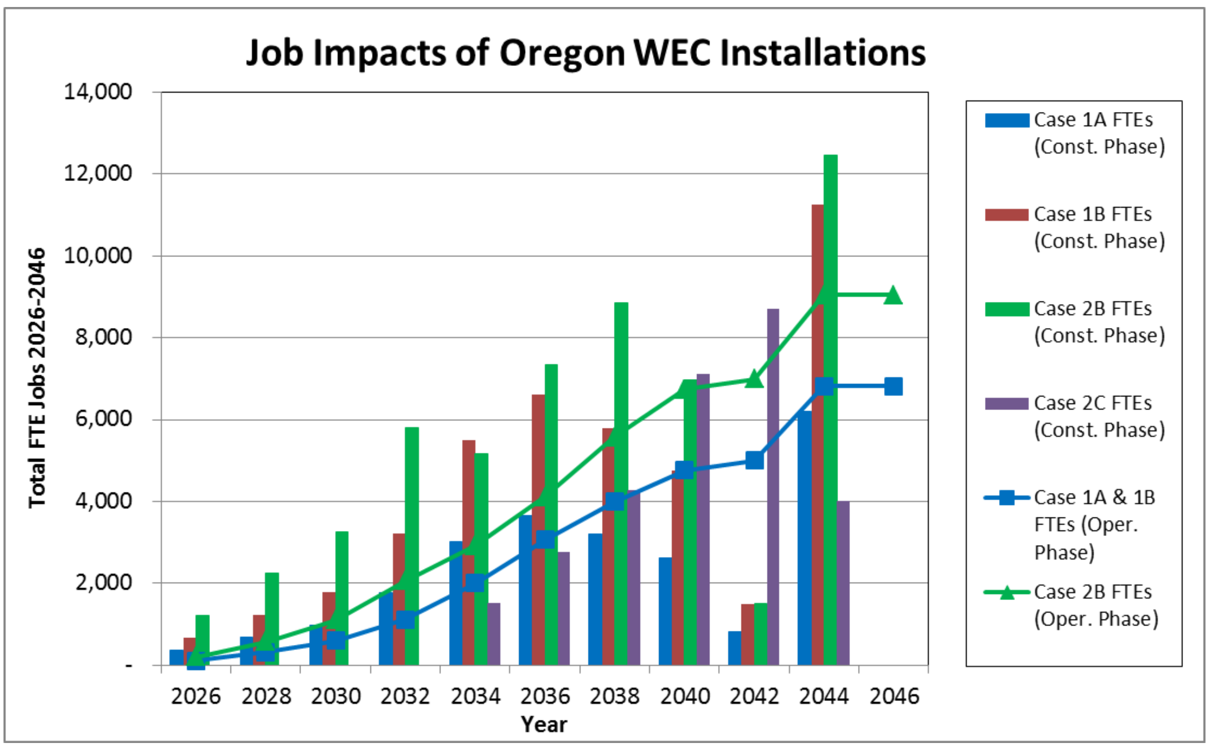

Figure 3-4. Estimated annual employment impacts from WEC deployment in Oregon

[11] By not including earnings from out-of-state workers in the analysis, we minimize the risk of overestimating the impacts in Oregon.

3.2.2 Operation and Maintenance Jobs

Over the WEC facility's anticipated 20- to 30-year operating life, long-term employees operate and maintain the facility by replacing components, troubleshooting electrical and mechanical malfunctions, repairing the hydraulic system, conducting diving operations, performing remotely operated vehicle operations, and conducting vessel operations. The analysis assumes that the majority of these positions are filled by Oregonians or by people who relocate to Oregon.

According to the analysis, large-scale WEC deployment in Oregon would result in 6,800 (Cases 1A and 1B) to 9,000 (Case 2B) ongoing jobs by the time 13,000 MW or 18,000 MW is operational (respectively).[12] Of these ongoing jobs, approximately 2,400–2,800 would be on-site positions; 3,100–4,400 would be equipment and supply chain sector jobs; and 1,300–1,900 would be positions in other sectors (e.g., restaurants, hotels, and retail stores) resulting from the induced activity.

3.3 State Lease Revenue

Under the assumptions described in Section 2.2.2, 13,000 MW of WEC installations would yield $7.4 million annually to the government of the State of Oregon and 18,000 MW of WEC installations will give $10 million annually to the state government. Revenue from leases is often used to fund and improve a state's infrastructure and public services.

4 Oregon Manufacturing Sensitivity Analysis

Economic development impacts depend, to a great degree, on the extent to which goods and services are acquired at the local level. WEC device and component manufacturing is anticipated to constitute 70% of the total construction cost of a WEC installation, thereby offering the largest potential source of economic development benefits at the state level. Because of this, Oregon is actively seeking to establish a WEC supply chain to maximize the economic benefits of its significant wave energy resource.[13]

To examine the effects of in-state manufacturing, this study includes a sensitivity analysis that investigates different values for the device local share. Case 1A assumes a 20% value for the device local share, whereas Case 1B assumes a 60% value for the device local share.

[12] Unlike the construction period, in which temporary workers are hired, during the operation and maintenance period, permanent workers are hired at the state level. Thus, the number of jobs reported during this period remains constant for every year that the WEC facility is operating. In other words, 13,000 MW of wind project development in Oregon would support 6,800 local jobs every year that the WEC facilities are in operation— approximately 20 years or the life of the project.

[13] http://oregonwave.org/about/

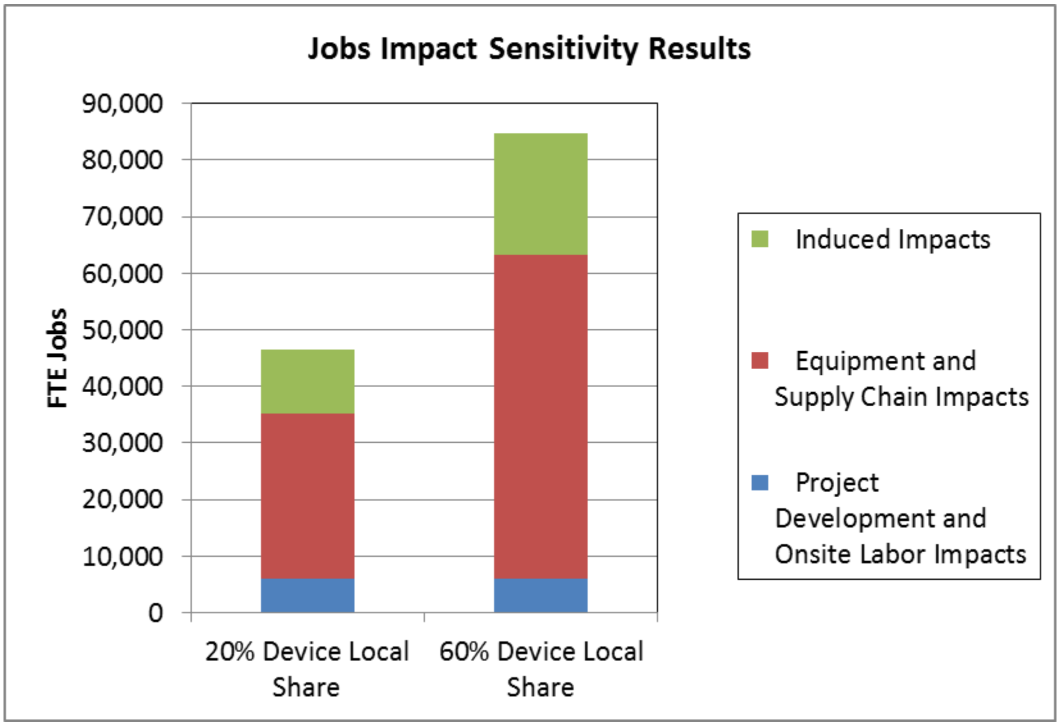

Figure 4-1. Manufacturing scenarios and associated job impacts during construction comparing WEC devices with 20% (1A) and 60% (1B) local components

Figure 4-1 shows the dramatic impact of the device local share on jobs: 13,000 MW of WEC facilities would support roughly 5,900 project development and on-site construction-phase FTE jobs. Figure 4-2, showing construction-phase economic activity for the two scenarios, again shows the supply chain economic activity dwarfing the economic activity related to developing and installing the projects. Establishing an in-state supply chain that captures even a modest portion of WEC installations will dramatically increase the economic impact of large-scale WEC deployment.

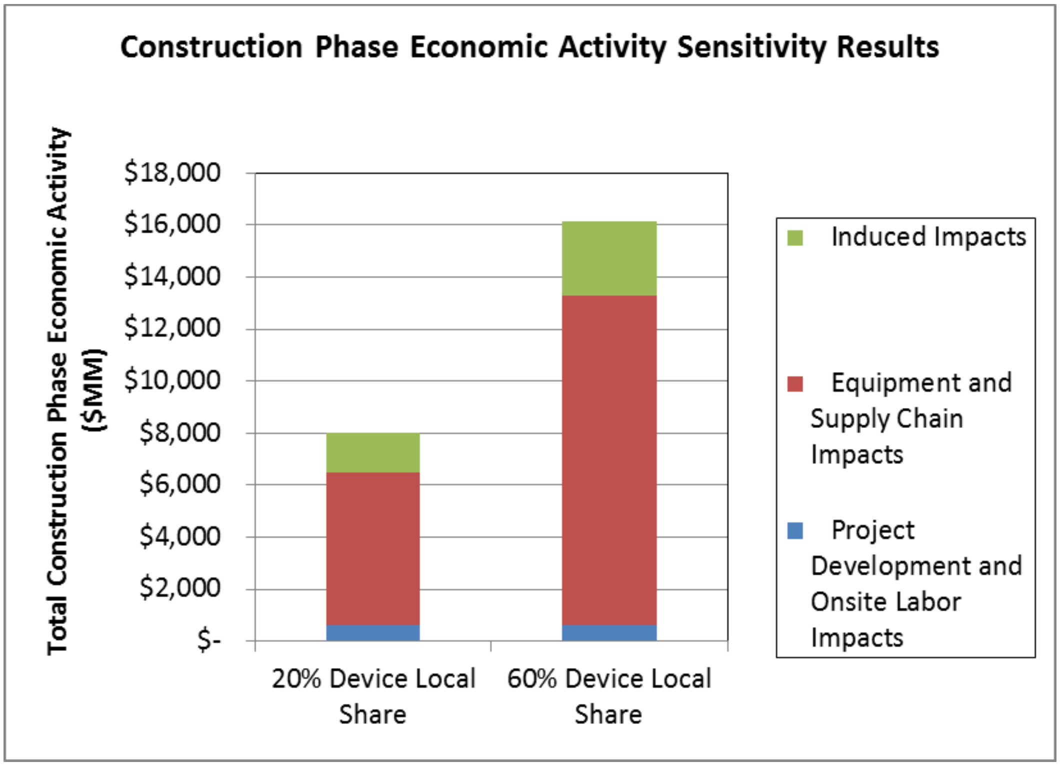

Figure 4-2. Manufacturing scenarios and associated economic impacts during the construction phase with 20% and 60% local share

5 Conclusion

Assuming technological advances and cost reductions in wave energy conversion, large-scale WEC deployment could have a significant impact on Oregon's economy. Over the 20-year analysis period, the ambitious deployment goal of 13,000 MW of WEC facilities (Case 1A) would support over 46,000 construction-phase FTE jobs and 6,800 ongoing jobs at the 13,000-MW deployment level. Gross economic activity for this case totals $8 billion during the construction phase, $1 billion by 2045 during the operations phase, and $1 billion annually after the analysis period. The economic impacts could be even greater if in-state manufacturers capture a larger portion of the Oregon market (Case 1B), there are more installations (Case 2B), or Oregon-based manufacturers capture a portion of the WEC market outside of Oregon (Case 2C).

The analysis shows that WEC device manufacturing appears to be the leading economic development driver in Oregon's potential wave energy industry. The scenario examined here has the potential to support significantly more jobs and associated economic impacts compared to other WEC activities. Specifically, for Case 1A, where in-state manufacturers capture 20% of the state market, the estimated supply chain jobs dwarf the jobs that are directly involved in developing and installing the facilities. Development of a local manufacturing base, as well as use of local labor and materials, could greatly enhance the economic impacts of WEC technology deployment and provide further opportunities for economic diversification and growth. As stated above, this NREL analysis assumed improvements in technology and in the cost of WEC devices. Without these, such high deployment of this generation technology would not be possible.

References

Augustine et al. (2012). *Renewable Electricity Future Study: Volume 2 Renewable Electricity Generation and Storage Technologies*. NREL/TP-6A20-52409-2. Golden, CO: National Renewable Energy Laboratory. Accessed April 10, 2014: http://www.nrel.gov/docs/fy12osti/52409-2.pdf.

Bureau of Ocean Energy Management (BOEM). (2010). Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf, (OCS-A-0478). Accessed April 10, 2014: http://www.boem.gov/uploadedFiles/BOEM/Renewable_Energy_Program/Studies/CapeWind_signed_lease.pdf.

BOEM. (2013a). Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf (OCS-A 0483). Department of the Interior. Retrieved from http://www.boem.gov/VA-Lease-OCS-A/.

BOEM. (2013b). Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf (OCS-A 0486). Department of the Interior. Retrieved from http://www.boem.gov/Renewable-Energy-Program/State-Activities/RI/Executed-Lease-OCS-A-0486.aspx.

BOEM. (2013c). Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf (OCS-A 0487). Department of the Interior. Retrieved from http://www.boem.gov/Renewable-Energy-Program/State-Activities/RI/Executed-Lease-OCS-A-0487.aspx.

Bowler, S. (May 2014). Email communication and phone conversation.

Carbon Trust. (2011). *Accelerating Marine Energy*. Accessed December 12, 2013: https://www.carbontrust.com/media/5675/ctc797.pdf.

Cohen, S. (December 2013). Email communication. National Renewable Energy Laboratory, Golden, CO.

Department of Trade and Industry. (2007). *Impact of Banding the Renewables Obligation – Costs of Electricity Production.* Accessed June 10, 2014: http://webarchive.nationalarchives.gov.uk/+/http://www.berr.gov.uk/files/file39038.pdf.

Energy Information Administration. (2014a). *Oregon State Profile and Energy Estimate*. Accessed August 22, 2014: http://www.eia.gov/state/analysis.cfm?sid=OR

Energy Information Administration. (2014b). *Annual Energy Outlook 2014. Market Trends: Electricity Demand*. Accessed September 2, 2014: http://www.eia.gov/forecasts/aeo/MT_electric.cfm

Goldberg, M.; Previsic, M. (2011). *JEDI Marine and Hydrokinetic Model: User Reference Guide*. NREL/SR-6A20-50402. Golden, CO: National Renewable Energy Laboratory. Accessed October 14, 2013: http://www.nrel.gov/docs/fy11osti/50402.pdf.

Ocean Energy Systems. (December 2013). Implementing Agreement on Ocean Energy Systems. 2013 Annual Report. Date Accessed: [include full date accessed]: http://www.ocean-energy-systems.org/oes_reports/annual_reports/ Accessed July 21, 2014.

O'Neil, Barbara. State of Oregon Department of Energy. Personal Communication. July 29, 2014.

Previsic, M.; Epler, J.; Hand, M.; Heimiller, D.; Short, W.; Eurek, K. (2012). *The Future Potential of Wave Power in the United States*. RE Vision Consulting on behalf of the U.S. Department of Energy. Accessed October 22, 2013: http://www.ourenergypolicy.org/wp-content/uploads/2012/10/The-Future-of-Wave-Power-MP-9-20-12.pdf.

Renewable UK. (2010). *Channeling the Energy: A Way Forward for the UK Wave & Tidal Industry Towards 2020.* Accessed June 10, 2014: http://www.marinerenewables.ca/wp-content/uploads/2012/11/Channeling-the-Energy-A-Way-Forward-for-the-UK-Wave-Tidal-Industry-Towards-2020.pdf.

Thresher, R. (August 2013). "Ocean Wave Energy Technology." Presented at the BOEM Offshore Renewable Energy Workshop.

Thresher, R. (January 2014). Personal communications. National Renewable Energy Laboratory, Golden, Colorado.

Appendix

Table A-1 shows the jobs in each JEDI category for each year of the scenario. The jobs listed during operating years are not cumulative, so to reach the total number of O&M jobs, the jobs from each year must be summed. For example, in 2026, there are 99 MW of WEC devices installed, and an estimated 111 Oregon jobs to operate and maintain that fleet. Two years later, when there are 199 MW installed, Table A-1 shows 201 jobs. To reach the total O&M jobs supported by projects installed in 2026-2028, we add operating year totals to get 312 Oregon-based operations and maintenance jobs that are ongoing, so they will exist over the life of the energy generation system. This same method of reporting is used in the following tables for operations-period jobs.

Table A-1. Case 1A Results – FTE Jobs Based on Annual Installations

JOBS	2026	2028	2030	2032	2034
During construction and installation period					
Project Development and Onsite Labor Impacts	94	171	249	446	765
Construction and Installation Labor	54	97	140	250	428
Construction and Installation Related Services	40	74	109	196	338
Equipment and Supply Chain Impacts	466	847	1,235	2,213	3,802
Induced Impacts	185	335	483	864	1,480
Total Impacts	745	1,353	1,967	3,522	6,047
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	40	72	104	184	315
Local Revenue and Supply Chain Impacts	50	90	130	231	396
Induced Impacts	21	39	56	100	171

JOBS	2036	2038	2040	2042	2044
During construction and installation period					
Project Development and Onsite Labor Impacts	923	808	662	210	1,572
Construction and Installation Labor	514	450	368	117	873
Construction and Installation Related Services	408	358	294	93	699
Equipment and Supply Chain Impacts	4,584	4,015	3,291	1,044	7,815
Induced Impacts	1,780	1,557	1,274	404	3,022
Total Impacts	7,287	6,380	5,228	1,658	12,409
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	381	333	273	86	648
Local Revenue and Supply Chain Impacts	478	417	343	109	814
Induced Impacts	207	181	149	47	354

Table A-2. Case 1A Results – Earnings Based on Annual Installations

Earnings [$MM (2012)]	2026	2028	2030	2032	2034
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 7.15	$ 12.38	$ 15.85	$ 27.53	$ 45.72
Construction and Installation Labor	$ 4.21	$ 7.02	$ 7.91	$ 13.26	$ 21.13
Construction and Installation Related Services	$ 2.93	$ 5.37	$ 7.94	$ 14.27	$ 24.60
Equipment and Supply Chain Impacts	$ 27.75	$ 50.38	$ 73.18	$ 130.97	$ 224.80
Induced Impacts	$ 7.89	$ 14.28	$ 20.58	$ 36.77	$ 62.99
Total Impacts	$ 42.79	$ 77.05	$ 109.60	$ 195.27	$ 333.52
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 2.11	$ 3.80	$ 5.47	$ 9.71	$ 16.64
Local Revenue and Supply Chain Impacts	$ 2.94	$ 5.30	$ 7.63	$ 13.55	$ 23.21
Induced Impacts	$ 0.91	$ 1.65	$ 2.39	$ 4.24	$ 7.28

Earnings [$MM (2012)]	2036	2038	2040	2042	2044
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 53.63	$ 45.98	$ 36.98	$ 11.62	$ 86.21
Construction and Installation Labor	$ 23.90	$ 19.88	$ 15.56	$ 4.82	$ 35.25
Construction and Installation Related Services	$ 29.73	$ 26.10	$ 21.42	$ 6.80	$ 50.96
Equipment and Supply Chain Impacts	$ 270.84	$ 237.11	$ 194.24	$ 61.59	$ 461.04
Induced Impacts	$ 75.78	$ 66.27	$ 54.24	$ 17.19	$ 128.62
Total Impacts	$ 400.25	$ 349.37	$ 285.47	$ 90.40	$ 675.87
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 20.11	$ 17.54	$ 14.40	$ 4.56	$ 34.17
Local Revenue and Supply Chain Impacts	$ 28.06	$ 24.49	$ 20.11	$ 6.38	$ 47.72
Induced Impacts	$ 8.82	$ 7.71	$ 6.34	$ 2.01	$ 15.08

Table A-3. Case 1A Results – Total Economic Impacts Based on Annual Installations

Output [$MM (2012)]	**2026**	**2028**	**2030**	**2032**	**2034**
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 11.76	$ 20.79	$ 28.19	$ 49.67	$ 83.81
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	$ 94.15	$ 170.79	$ 247.49	$ 442.73	$ 759.51
Induced Impacts	$ 24.85	$ 44.99	$ 64.83	$ 115.84	$ 198.46
Total Impacts	$ 130.76	$ 236.57	$ 340.51	$ 608.24	$ 1,041.78
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 2.11	$ 3.80	$ 5.47	$ 9.71	$ 16.64
Local Revenue and Supply Chain Impacts	$ 11.35	$ 20.47	$ 29.45	$ 52.28	$ 89.57
Induced Impacts	$ 2.88	$ 5.20	$ 7.52	$ 13.37	$ 22.95

Output [$MM (2012)]	**2036**	**2038**	**2040**	**2042**	**2044**
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 99.60	$ 86.28	$ 70.04	$ 22.11	$ 164.76
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	$ 914.66	$ 800.52	$ 655.61	$ 207.85	$ 1,555.69
Induced Impacts	$ 238.75	$ 208.80	$ 170.88	$ 54.16	$ 405.22
Total Impacts	$ 1,253.01	$ 1,095.60	$ 896.53	$ 284.11	$ 2,125.67
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 20.11	$ 17.54	$ 14.40	$ 4.56	$ 34.17
Local Revenue and Supply Chain Impacts	$ 108.28	$ 94.48	$ 77.57	$ 24.60	$ 184.12
Induced Impacts	$ 27.80	$ 24.30	$ 19.98	$ 6.34	$ 47.51

Table A-4. Case 1B Results – FTE Jobs Based on Annual Installations

JOBS	2026	2028	2030	2032	2034
During construction and installation period					
Project Development and Onsite Labor Impacts	94	171	249	446	765
Construction and Installation Labor	54	97	140	250	428
Construction and Installation Related Services	40	74	109	196	338
Equipment and Supply Chain Impacts	923	1,674	2,426	4,339	7,443
Induced Impacts	350	633	912	1,629	2,790
Total Impacts	1,366	2,478	3,586	6,413	10,999
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	40	72	104	184	315
Local Revenue and Supply Chain Impacts	50	90	130	231	396
Induced Impacts	21	39	56	100	171

JOBS	2036	2038	2040	2042	2044
During construction and installation period					
Project Development and Onsite Labor Impacts	923	808	662	210	1,572
Construction and Installation Labor	514	450	368	117	873
Construction and Installation Related Services	408	358	294	93	699
Equipment and Supply Chain Impacts	8,964	7,845	6,425	2,037	15,246
Induced Impacts	3,356	2,935	2,402	761	5,695
Total Impacts	13,242	11,588	9,489	3,008	22,513
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	381	333	273	86	648
Local Revenue and Supply Chain Impacts	478	417	343	109	814
Induced Impacts	207	181	149	47	354

Table A-5. Case 1B Results – Earnings Based on Annual Installations

Earnings [$MM (2012)]	2026	2028	2030	2032	2034
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 7.15	$ 12.38	$ 15.85	$ 27.53	$ 45.72
Construction and Installation Labor	$ 4.21	$ 7.02	$ 7.91	$ 13.26	$ 21.13
Construction and Installation Related Services	$ 2.93	$ 5.37	$ 7.94	$ 14.27	$ 24.60
Equipment and Supply Chain Impacts	$ 56.31	$ 102.05	$ 147.55	$ 263.81	$ 452.33
Induced Impacts	$ 14.89	$ 26.94	$ 38.80	$ 69.32	$ 118.75
Total Impacts	$ 78.34	$ 141.37	$ 202.20	$ 360.67	$ 616.81
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 2.11	$ 3.80	$ 5.47	$ 9.71	$ 16.64
Local Revenue and Supply Chain Impacts	$ 2.94	$ 5.30	$ 7.63	$ 13.55	$ 23.21
Induced Impacts	$ 0.91	$ 1.65	$ 2.39	$ 4.24	$ 7.28

Earnings [$MM (2012)]	2036	2038	2040	2042	2044
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 53.63	$ 45.98	$ 36.98	$ 11.62	$ 86.21
Construction and Installation Labor	$ 23.90	$ 19.88	$ 15.56	$ 4.82	$ 35.25
Construction and Installation Related Services	$ 29.73	$ 26.10	$ 21.42	$ 6.80	$ 50.96
Equipment and Supply Chain Impacts	$ 544.50	$ 476.40	$ 390.05	$ 123.64	$ 925.30
Induced Impacts	$ 142.85	$ 124.91	$ 102.22	$ 32.40	$ 242.39
Total Impacts	$ 740.98	$ 647.29	$ 529.26	$ 167.66	$ 1,253.91
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 20.11	$ 17.54	$ 14.40	$ 4.56	$ 34.17
Local Revenue and Supply Chain Impacts	$ 28.06	$ 24.49	$ 20.11	$ 6.38	$ 47.72
Induced Impacts	$ 8.82	$ 7.71	$ 6.34	$ 2.01	$ 15.08

Table A-6. Case 1B Results – Total Economic Impacts Based on Annual Installations

Output [$MM (2012)]	**2026**	**2028**	**2030**	**2032**	**2034**
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 11.76	$ 20.79	$ 28.19	$ 49.67	$ 83.81
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	$ 204.96	$ 371.25	$ 536.05	$ 958.16	$ 1,642.33
Induced Impacts	$ 46.91	$ 84.88	$ 122.25	$ 218.40	$ 374.14
Total Impacts	$ 263.63	$ 476.93	$ 686.49	$ 1,226.23	$ 2,100.28
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 2.11	$ 3.80	$ 5.47	$ 9.71	$ 16.64
Local Revenue and Supply Chain Impacts	$ 11.35	$ 20.47	$ 29.45	$ 52.28	$ 89.57
Induced Impacts	$ 2.88	$ 5.20	$ 7.52	$ 13.37	$ 22.95

Output [$MM (2012)]	**2036**	**2038**	**2040**	**2042**	**2044**
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 99.60	$ 86.28	$ 70.04	$ 22.11	$ 164.76
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	$ 1,976.49	$ 1,728.94	$ 1,415.34	$ 448.62	$ 3,357.02
Induced Impacts	$ 450.05	$ 393.55	$ 322.07	$ 102.07	$ 763.68
Total Impacts	$ 2,526.13	$ 2,208.77	$ 1,807.45	$ 572.79	$ 4,285.46
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 20.11	$ 17.54	$ 14.40	$ 4.56	$ 34.17
Local Revenue and Supply Chain Impacts	$ 108.28	$ 94.48	$ 77.57	$ 24.60	$ 184.12
Induced Impacts	$ 27.80	$ 24.30	$ 19.98	$ 6.34	$ 47.51

Table A-7. Case 2B Results – FTE Jobs Based on Annual Installations

JOBS	2026	2028	2030	2032	2034
During construction and installation period					
Project Development and Onsite Labor Impacts	169	309	453	808	719
Construction and Installation Labor	96	175	254	452	401
Construction and Installation Related Services	73	134	199	357	318
Equipment and Supply Chain Impacts	1,657	3,023	4,407	7,861	6,990
Induced Impacts	627	1,140	1,654	2,946	2,616
Total Impacts	2,453	4,472	6,514	11,615	10,326
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	62	114	162	294	260
Local Revenue and Supply Chain Impacts	100	182	259	469	416
Induced Impacts	41	75	108	196	174

JOBS	2036	2038	2040	2042	2044
During construction and installation period					
Project Development and Onsite Labor Impacts	1,025	1,236	976	210	1,743
Construction and Installation Labor	570	687	541	116	966
Construction and Installation Related Services	455	549	434	93	777
Equipment and Supply Chain Impacts	9,948	11,990	9,457	2,032	16,892
Induced Impacts	3,720	4,480	3,531	758	6,304
Total Impacts	14,693	17,706	13,964	3,000	24,940
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	369	445	357	75	626
Local Revenue and Supply Chain Impacts	589	712	572	121	1,002
Induced Impacts	247	299	240	51	422

Table A-8. Case 2B Results – Earnings Based on Annual Installations

Earnings [$MM (2012)]	2026	2028	2030	2032	2034
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 12.26	$ 21.42	$ 27.94	$ 48.17	$ 41.64
Construction and Installation Labor	$ 6.95	$ 11.66	$ 13.44	$ 22.19	$ 18.44
Construction and Installation Related Services	$ 5.31	$ 9.76	$ 14.50	$ 25.98	$ 23.20
Equipment and Supply Chain Impacts	$ 101.03	$ 184.13	$ 267.96	$ 477.65	$ 424.57
Induced Impacts	$ 26.67	$ 48.54	$ 70.41	$ 125.39	$ 111.37
Total Impacts	$ 139.96	$ 254.09	$ 366.31	$ 651.22	$ 577.58
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 3.30	$ 6.00	$ 8.56	$ 15.49	$ 13.72
Local Revenue and Supply Chain Impacts	$ 5.88	$ 10.70	$ 15.26	$ 27.65	$ 24.49
Induced Impacts	$ 1.76	$ 3.21	$ 4.60	$ 8.34	$ 7.40

Earnings [$MM (2012)]	2036	2038	2040	2042	2044
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 57.82	$ 68.42	$ 53.04	$ 11.29	$ 93.45
Construction and Installation Labor	$ 24.68	$ 28.39	$ 21.39	$ 4.48	$ 36.83
Construction and Installation Related Services	$ 33.13	$ 40.03	$ 31.65	$ 6.81	$ 56.63
Equipment and Supply Chain Impacts	$ 604.03	$ 727.79	$ 573.93	$ 123.27	$ 1,024.91
Induced Impacts	$ 158.34	$ 190.70	$ 150.31	$ 32.28	$ 268.34
Total Impacts	$ 820.19	$ 986.90	$ 777.27	$ 166.83	$ 1,386.70
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 19.45	$ 23.50	$ 18.86	$ 3.98	$ 33.05
Local Revenue and Supply Chain Impacts	$ 34.72	$ 41.96	$ 33.69	$ 7.11	$ 59.03
Induced Impacts	$ 10.51	$ 12.72	$ 10.23	$ 2.16	$ 17.96

Table A-9. Case 2B Results – Total Economic Impacts Based on Annual Installations

Output [$MM (2012)]	2026	2028	2030	2032	2034
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 20.59	$ 36.68	$ 50.42	$ 88.40	$ 77.50
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	$ 367.52	$ 669.52	$ 973.22	$ 1,734.24	$ 1,541.08
Induced Impacts	$ 84.03	$ 152.93	$ 221.83	$ 395.06	$ 350.88
Total Impacts	$ 472.14	$ 859.13	$ 1,245.47	$ 2,217.69	$ 1,969.46
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 3.30	$ 6.00	$ 8.56	$ 15.49	$ 13.72
Local Revenue and Supply Chain Impacts	$ 22.75	$ 41.44	$ 59.09	$ 107.04	$ 94.80
Induced Impacts	$ 5.54	$ 10.11	$ 14.48	$ 26.28	$ 23.32
Output [$MM (2012)]	**2036**	**2038**	**2040**	**2042**	**2044**
During construction and installation period					
Project Development and Onsite Labor Impacts	$ 108.96	$ 130.15	$ 101.79	$ 21.77	$ 180.64
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	$ 2,191.98	$ 2,640.65	$ 2,082.07	$ 447.15	$ 3,717.69
Induced Impacts	$ 498.88	$ 600.81	$ 473.58	$ 101.69	$ 845.43
Total Impacts	$ 2,799.82	$ 3,371.61	$ 2,657.44	$ 570.61	$ 4,743.76
During operating years					
Onsite Labor Impacts					
Hydro Project Labor Only	$ 19.45	$ 23.50	$ 18.86	$ 3.98	$ 33.05
Local Revenue and Supply Chain Impacts	$ 134.41	$ 162.41	$ 130.40	$ 27.53	$ 228.50
Induced Impacts	$ 33.13	$ 40.09	$ 32.24	$ 6.82	$ 56.60

Table A-10. Case 2C Results – FTE Jobs, Earnings, and Total Economic Impacts Based on Annual Installations

JOBS	2026	2028	2030	2032	2034
During construction and installation period					
Project Development and Onsite Labor Impacts	0	0	0	0	0
Construction and Installation Labor	0	0	0	0	0
Construction and Installation Related Services	0	0	0	0	0
Equipment and Supply Chain Impacts	0	0	0	0	2,216
Induced Impacts	0	0	0	0	797
Total Impacts	0	0	0	0	3,013

JOBS	2036	2038	2040	2042	2044
During construction and installation period					
Project Development and Onsite Labor Impacts	0	0	0	0	0
Construction and Installation Labor	0	0	0	0	0
Construction and Installation Related Services	0	0	0	0	0
Equipment and Supply Chain Impacts	4,086	6,300	10,483	12,823	5,888
Induced Impacts	1,470	2,266	3,771	4,613	2,118
Total Impacts	5,556	8,566	14,253	17,436	8,006

Earnings [$MM (2012)]	2026	2028	2030	2032	2034
During construction and installation period					
Project Development and Onsite Labor Impacts	$ -	$ -	$ -	$ -	$ -
Construction and Installation Labor	$ -	$ -	$ -	$ -	$ -
Construction and Installation Related Services	$ -	$ -	$ -	$ -	$ -
Equipment and Supply Chain Impacts	$ 0.16	$ 0.15	$ 0.11	$ 0.10	$ 138.45
Induced Impacts	$ 0.04	$ 0.04	$ 0.03	$ 0.02	$ 33.93
Total Impacts	$ 0.20	$ 0.18	$ 0.13	$ 0.12	$ 172.38

Earnings [$MM (2012)]	2036	2038	2040	2042	2044
During construction and installation period					
Project Development and Onsite Labor Impacts	$ -	$ -	$ -	$ -	$ -
Construction and Installation Labor	$ -	$ -	$ -	$ -	$ -
Construction and Installation Related Services	$ -	$ -	$ -	$ -	$ -
Equipment and Supply Chain Impacts	$ 255.32	$ 393.61	$ 654.94	$ 801.19	$ 367.86
Induced Impacts	$ 62.57	$ 96.46	$ 160.50	$ 196.35	$ 90.15
Total Impacts	$ 317.89	$ 490.07	$ 815.45	$ 997.54	$ 458.01

Output [$MM (2012)]	2026	2028	2030	2032	2034
During construction and installation period					
Project Development and Onsite Labor Impacts	$ -	$ -	$ -	$ -	$ -
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	$ 0.63	$ 0.57	$ 0.41	$ 0.37	$ 537.18
Induced Impacts	$ 0.13	$ 0.11	$ 0.08	$ 0.07	$ 106.90
Total Impacts	$ 0.76	$ 0.68	$ 0.50	$ 0.44	$ 644.08

Output [$MM (2012)]	2036	2038	2040	2042	2044
During construction and installation period					
Project Development and Onsite Labor Impacts	$ -	$ -	$ -	$ -	$ -
Construction and Installation Labor					
Construction and Installation Related Services					
Equipment and Supply Chain Impacts	$ 990.65	$ 1,527.22	$ 2,541.20	$ 3,108.65	$ 1,427.30
Induced Impacts	$ 197.13	$ 303.91	$ 505.69	$ 618.61	$ 284.03
Total Impacts	$ 1,187.78	$ 1,831.13	$ 3,046.88	$ 3,727.26	$ 1,711.32